

**HISTORICAL METEOROLOGICAL ANALYSIS IN
SUPPORT OF THE 2003 SAN JOAQUIN VALLEY PM₁₀
STATE IMPLEMENTATION PLAN
FINAL REPORT**

**Prepared By:
Shawn R. Ferreria
Air Quality Meteorologist / Atmospheric Scientist
and
Evan M. Shipp
Supervising Air Quality Meteorologist
San Joaquin Valley Air Pollution Control District**

January 24, 2005

ACKNOWLEDGEMENTS

We wish to acknowledge the contributions of Air Resources Board Staff, Ms. Karen Magliano, Ms. Kasia Turkiewicz, and Mr. Rich Hackney who provided valuable information in the compiling and reviewing of this document. We wish to also acknowledge the contribution of the members of the PM₁₀ Modeling group who provided extremely useful discussions during the planning, intermediate stages, and development of this document.

TABLE OF CONTENTS

<u>Section</u>	<u>Page</u>
ACKNOWLEDGEMENTS.....	ii
LIST OF FIGURES.....	v
LIST OF TABLES.....	vi
EXECUTIVE SUMMARY.....	vii
1.0 NOVEMBER 6, 1997 EPISODE SYNOPTIC METEOROLOGICAL DISCUSSION.....	1
2.0 DECEMBER 31, 1998 AND JANUARY 12, 1999 EPISODE SYNOPTIC METEOROLOGICAL DISCUSSION.....	4
3.0 INTEGRATED ANALYSIS OF ATMOSPHERIC CHEMISTRY AND METEOROLOGY DURING THE JANUARY 12, 1999 EPISODE.....	10
4.0 OCTOBER 21, 1999 EPISODE SYNOPTIC METEOROLOGICAL DISCUSSION.....	15
5.0 INTEGRATED ANALYSIS OF ATMOSPHERIC CHEMISTRY AND METEOROLOGY DURING THE OCTOBER 21, 1999 EPISODE	18
6.0 NOVEMBER 14, 1999 EPISODE SYNOPTIC METEOROLOGICAL DISCUSSION.....	22
7.0 INTEGRATED ANALYSIS OF ATMOSPHERIC CHEMISTRY AND METEOROLOGY DURING THE NOVEMBER 14, 1999 EPISODE.....	26
8.0 DECEMBER 17 AND 23, 1999 EPISODE SYNOPTIC METEOROLOGICAL DISCUSSION.....	29
9.0 INTEGRATED ANALYSIS OF ATMOSPHERIC CHEMISTRY AND METEOROLOGY DURING THE DECEMBER 1999 EPISODE.....	35
10.0 DECEMBER 1999 AND JANUARY 2000 PM _{2.5} & PM ₁₀ METEOROLOGICAL DISCUSSION.....	40
11.0 DECEMBER 2000 AND JANUARY 2001 EPISODE SYNOPTIC METEOROLOGICAL DISCUSSION.....	51
12.0 DISPERSION METEOROLOGY FOR THE FALL 2000 AND WINTER 2001 CRPAQS.....	58

13.0	INTEGRATED ANALYSIS OF ATMOSPHERIC CHEMISTRY AND METEOROLOGY DURING THE JANUARY 2001 EPISODE.....	69
14.0	NOVEMBER 9, 2001 EPISODE SYNOPTIC METEOROLOGICAL DISCUSSION.....	77
15.0	INTEGRATED ANALYSIS OF ATMOSPHERIC CHEMISTRY AND METEOROLOGY DURING THE NOVEMBER 9, 2001 EPISODE.....	81
16.0	MAY 19 AND 20, 2002 EPISODE SYNOPTIC METEOROLOGICAL DISCUSSION.....	84
17.0	REFERENCES.....	90

LIST OF FIGURES

1	Corcoran PM ₁₀ , Fresno Precipitation, and T850 Stability Fall 1997.....	1
2	Atmospheric Temperature Profile at Fresno on November 06, 1997.....	2
3	T850 Stability and Precipitation vs. PM ₁₀ at Bakersfield (12/98-01/99).....	4
4	Atmospheric Temperature Profile at Bakersfield on 12/31/1998.....	6
5	Atmospheric Temperature Profile at Bakersfield on 01/12/1999.....	8
6	Bakersfield-Golden(Coarse, PM ₁₀ & _{2.5}) 12/1998 & 01/1999.....	11
7	Visalia and Oildale PM ₁₀ December 1998 & January 1999.....	11
8	Fresno-1 st PM ₁₀ & _{2.5} , Precipitation, T850 Stability and Model PM ₁₀ 10/99...	16
9	Atmospheric Temperature Profile at Fresno on October 21, 1999.....	17
10	October 1999 Solar Intensity.....	17
11	Corcoran (Coarse, PM ₁₀ & _{2.5}) and Fresno-1 st (PM _{2.5}) 10/21/1999.....	18
12	Turlock-Minareet and Fresno-Drum. PM ₁₀ and Fresno-1 st (PM _{2.5}) 10/21/99...	19
13	T850 Stability & Precipitation vs. PM ₁₀ & _{2.5} at Bakersfield-Gold F/W99....	22
14	Atmospheric Temperature Profile at Bakersfield on 11/14/99.....	24
15	Bakersfield Golden (PM _{2.5} &Coarse) and Fresno-1 st (PM _{2.5}) 11/14/99.....	26
16	Bakersfield Calif. (Coarse, PM _{2.5} & ₁₀) and Fresno-1 st (PM _{2.5}) 11/14/99.....	27
17	T850 Stability & Precipitation at Hanford vs. PM ₁₀ & _{2.5} at Corcoran 12/99...	29
18	Atmospheric Temperature Profile at Fresno on December 17, 1999.....	31
19	T850 Stability and Precipitation vs. PM ₁₀ & _{2.5} at Hanford, Dec. 1999.....	33
20	Atmospheric Temperature Profile at Fresno on December 23, 1999.....	34
21	Corcoran (Coarse, PM _{2.5} & ₁₀) and Fresno-1 st (PM _{2.5}) 12/17/99.....	35
22	Fresno Drummond (PM ₁₀) and Fresno 1 st (PM _{2.5}) 12/17/99.....	36
23	Hanford (PM ₁₀) and Fresno 1 st (PM _{2.5}) 12/23/99.....	38
24	T850 Stability vs. PM ₁₀ and PM _{2.5} at Corcoran for 12/99 and 01/00.....	40
25	PM _{2.5} at Fresno 1 st and Bakersfield California for 12/99 and 01/00.....	42
26	Atmospheric Temperature Profile at Fresno on Dec. 17, 1999.....	43
27	T850 Stability and Precipitation vs. PM ₁₀ at Hanford 12/99.....	46
28	Atmospheric Temperature Profile at Fresno on Dec. 23, 1999.....	46
29	Wind Rose at Clovis Air Monitoring for 12/17 & 12/23/99, & 01/07/2000.....	49
30	Fresno-1 st Stability and Pollutant Trends for Fall 2000 & Winter 2001.....	52
31	Fresno-1 st Fall 2000 and Winter 2001 Episode.....	59
32	Fresno-1 st (Coarse) & (PM _{2.5}) January 2001 Episode.....	65
33	Bakersfield California (Coarse) &(PM _{2.5}) January 2001 Episode.....	65
34	Bakersfield Golden (Coarse, PM ₁₀ & _{2.5}) &Baker. Cal. (PM _{2.5}) '01 Episode....	65
35	Hanford, Oildale, & Modesto (PM ₁₀) & Fresno-1 st &Baker. Cal. (PM _{2.5}).....	66
36	Fresno-1 st (Coarse) and (PM _{2.5}) January 2001 Episode.....	70
37	Bakersfield California (Coarse) and (PM _{2.5}) January 2001 Episode.....	72
38	Bakersfield Golden (Coarse, PM ₁₀ & _{2.5}) &Baker. Cal. (PM _{2.5}) '01 Episode....	72
39	Hanford, Oildale, & Modesto (PM ₁₀) & Fresno-1 st &Baker. Cal. (PM _{2.5}) January 2001 Episode.....	72
40	T850 Stability & Precipitation vs. PM ₁₀ at Hanford, Fall & Winter 2001.....	77
41	Atmospheric Temperature Profile at Fresno on November 9, 2001.....	79
42	Hanford (PM ₁₀) and Fresno 1 st (PM _{2.5}), November 9, 2001.....	81
43	Corcoran (PM _{2.5} &Coarse) and Fresno-1 st (PM _{2.5}), November 9, 2001.....	82

LIST OF FIGURES (continued)

44	Visalia Lower Air Profiler Image for May 19 – May 20, 2002.....	86
45	Lost Hills Lower Air Profiler Image for May 19 – May 20, 2002.....	86
46	Hourly Ave. Wind Speeds at Bakersfield Golden on 5/19 – 5/20, 2002.....	89

LIST OF TABLES

1	Federal Reference Method (FRM) Daily Ave. PM Measurements, 11/6/97....	1
2	24 hr. Ave. Wind Speeds at SJVAPCD, ASOS, & CIMIS sites for 11/6/97.....	3
3	FRM Daily Ave. PM Measurements for sites across SJV for 12/31/1998.....	5
4	24 hr. Ave. Wind Speeds at SJVAPCD, ASOS, & CIMIS sites for 12/31/98...	6
5	FRM Daily Ave. PM Measurements for sites across SJV for 01/12/1999.....	7
6	24 hr. Ave. Wind Speeds at SJVAPCD, ASOS, & CIMIS sites for 1/12/99.....	8
7	FRM Daily Ave. PM Measurements for sites across the SJV for 11/14/99.....	23
8	24 hr. Ave. Wind Speeds at SJVAPCD, ASOS, & CIMIS sites for 11/14/99...	25
9	FRM Daily Ave. PM Measurements for sites across the SJV for 12/17/99.....	30
10	24 hr. Ave. Wind Speeds at SJVAPCD, ASOS, & CIMIS sites for 12/17/99...	31
11	FRM Daily Ave. PM Measurements for sites across the SJV for 12/23/99.....	32
12	CRPAQS Daily Ave. PM Meas. for Fresno-Dru. & Hanford for 12/23/99.....	32
13	24 hr. Ave. Wind Speeds at SJVAPCD, ASOS, & CIMIS sites for 12/23/99...	34
14	FRM Daily Ave. PM Measurements for sites across the SJV for 12/17/99.....	42
15	24 hr. Ave. Wind Speeds at SJVAPCD, ASOS, & CIMIS sites for 12/17/99....	44
16	FRM Daily Ave. PM Measurements for sites across the SJV for 12/23/99.....	45
17	CRPAQS Daily Ave. PM Meas. for Fresno-Dru. & Hanford for 12/23/99.....	45
18	24 hr. Ave. Wind Speeds at SJVAPCD, ASOS, & CIMIS sites for 12/23/99...	47
19	CRPAQS Episode Event Summary Table at Fresno.....	53
20	PM ₁₀ Chemical Composition Data for Jan. 1, 4, & 7 2001 at selected sites....	64
21	PM ₁₀ Chemical Composition Data for Jan. 1, 4, & 7 2001 at selected sites....	71
22	FRM Daily Ave. PM Measurements for sites across the SJV for 11/9/2001....	78
23	24 hr. Ave. Wind Speeds at SJVAPCD, ASOS, & CIMIS sites for 11/9/2001....	79
24	Peak & Daily Ave. PM Measurements for sites across the SJV for 5/19/2002..	84
25	24 hr. Ave. Wind Speeds at SJVAPCD, ASOS, & CIMIS sites for 5/19/2002...	85
26	Peak & Daily Ave. PM Measurements for sites across the SJV for 5/20/2002..	87
27	24 hr. Ave. Wind Speeds at SJVAPCD, ASOS, & CIMIS sites for 5/20/2002...	88

EXECUTIVE SUMMARY

Study Purpose

This document characterizes meteorology and air quality experienced during the Particulate Matter (PM) season from November 1997 through May 2002. The evaluation was focused on understanding the causes of particulate matter concentrations that exceeded the National Ambient Air Quality Standards (NAAQS) in the San Joaquin Valley by exploring the meteorology and chemistry of each episode. Utilizing daily PM_{2.5} and PM₁₀ concentrations, chemical composition, and meteorological data, each PM₁₀ episode was identified. An episode was defined as the complete period, from the beginning through the end, where PM₁₀ concentrations increased to a peak that exceeded the Federal PM₁₀ Standard of 150 µg/m³ and then decreased dramatically as atmospheric dispersion conditions improved. This analysis was a collaborative effort with contributions from the Air Resources Board staff, including Ms. Karen Magliano, Ms. Kasia Turkiewicz, and Mr. Rich Hackney and also members of the PM₁₀ modeling group. The general objectives of the characterization analyses are to provide:

1. Support for the 2003 San Joaquin Valley PM State Implementation Plan (SIP) and other District programs
2. Development and improvement of the conceptual model
3. An understanding of San Joaquin Valley meteorology and how it influences particulate formation and accumulation.

Summary of Findings

During each episode, cooler air at the surface and warm air above the mixing layer trapped pollutants under a strong temperature inversion. Horizontal movement of air was minimal and disorganized reducing dispersion and transport of pollutants. These conditions caused particulates to increase throughout the San Joaquin Valley. Under the poor mixing conditions, coarse and fine particulates accumulated leading to high particulate concentrations.

A majority of the episodes were characterized by a prolonged period (two to three weeks) of limited mixing and light wind flow. The November 14, 1999 and November 9, 2001 were an exception, when strong stability and local emissions drove concentrations at the PM₁₀ monitoring sites over the NAAQS in less than a week and a half. Winter exceedances (December and January) were characterized by an increase in fine particles to a level that dominated filter samples. Fall exceedances (October and November) were dominated by coarse particles. To a lesser extent in the fall and a greater extent in the winter, cool damp mornings and restricted vertical air movement contributed to the formation of nitrates and sulfates. Total carbon concentrations from combustion sources remained proportionally the same during the fall and winter exceedances. Due to stagnant weather conditions, the elevated PM₁₀ and PM_{2.5} measurements that resulted in an exceedance of the NAAQS were caused primarily by

local emission sources, rather than background or long-range transport of material in most of the episodes. An analysis of a wind blow dust event that occurred on May 19 and 20, 2002 was also done.

As stated above during most episodes winds and transport were minimal. However, during the CRPAQS 2001 episode given the length of the episode and the large contributions from secondary components, there was an underlying regional component to this episode as it progressed. Local carbon and geologic contributions added to this regional component and influenced site to site concentration variations. As the CRPAQS episode continued, PM and precursors became more homogeneous across the region. This resulted in PM_{2.5} concentrations at rural sites lagging those of urban sites, and rural concentrations continued to build throughout the episode.

The October 1999 particulate episode was unique and did not follow the general meteorological and chemical pattern observed in other episodes. Concentrations during this event were dominated by geological particles (PM₁₀), with significant contributions from fine particulates of ammonium nitrate and sulfate and total carbon. The abundance of fine particulates in the samples may have been due to abnormalities in atmospheric chemistry reactions. Due to several wildfires to the north and a major tire fire at Westley earlier in October, particulate loading aloft may have decreased solar radiation intensity measurements across the Valley Floor. With reduced solar radiation, the atmospheric chemistry reactions may have changed from the ozone forming regime of mid-October to the secondary particulate regime of late November. Although geological particulates dominated the samples, fine fractions of PM were elevated. Limited afternoon heating and stagnant weather conditions, resulted in local sources driving PM₁₀ concentrations to exceed the NAAQS.

With these similarities and differences among the episodes, each PM₁₀ episode is discussed in detail in the following sections. PM₁₀ and PM_{2.5} concentrations, chemical composition, and meteorological data around the exceedance dates are evaluated and analyzed to identify the characteristics and uniqueness of the exceedances at the FRM and CRPAQS PM₁₀ and PM_{2.5} monitoring sites.

1.0 NOVEMBER 06, 1997 EPISODE SYNOPTIC METEOROLOGICAL DISCUSSION

October 11 – November 7, 1997

After a cold front and trough passage on October 11th, high pressure from the eastern Pacific built into the region, with increasing stability and poor dispersion conditions through the exceedance date on November 6th, **Figure 1**. At Corcoran, Patterson Ave., a 24-hour PM₁₀ (Particulate Matter) concentration of 199 µg/m³ was measured. **Table 1** outlines federal reference method (FRM) Daily Average Particulate Matter Measurements for sites across the San Joaquin Valley (SJV). In order to understand the variability of these measurements, an in depth examination of the synoptic pattern and surface winds and observations, and aircraft soundings leading to the episode were analyzed.

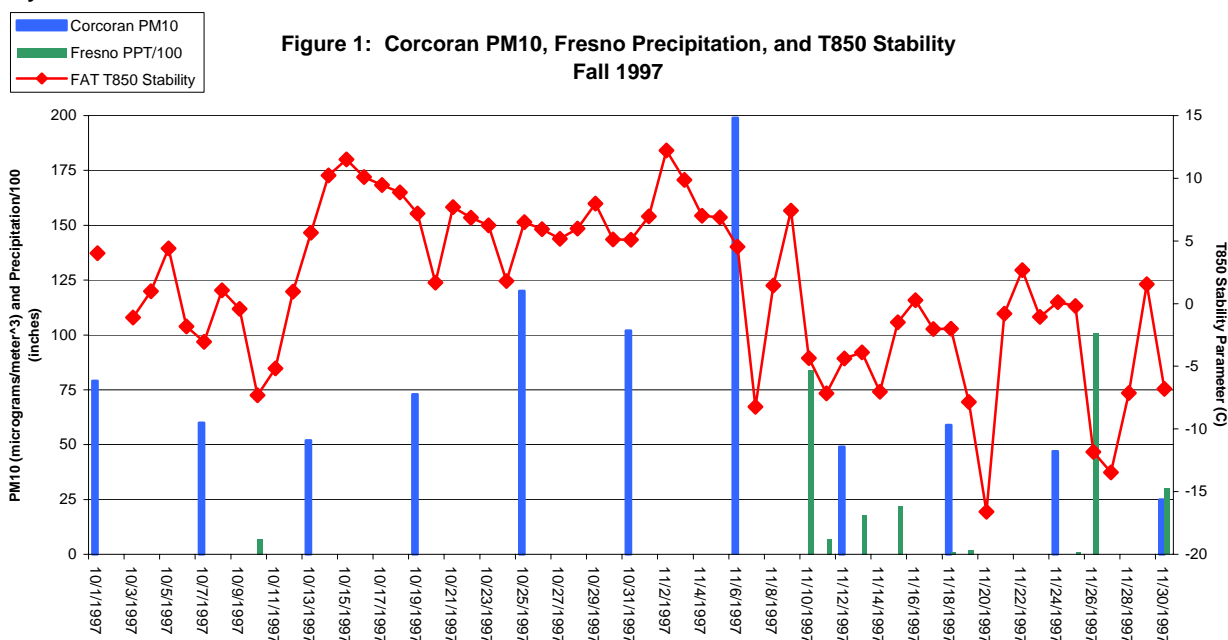


TABLE 1: Federal Reference Method (FRM) Daily Average Particulate Matter Measurements for sites across the SJV for November 06, 1997.

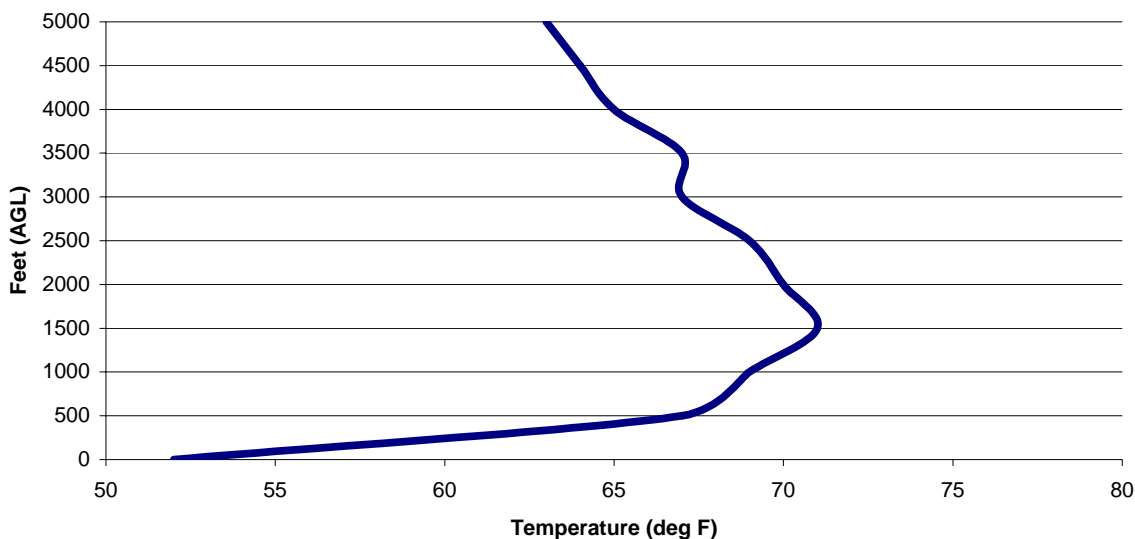
	FRM		FRM		FRM
Site Name	24-Avg.	Site Name	24-Avg.	Site Name	24-Avg.
Corcoran*	199	Visalia	83	Bakersfield-CA	95
Corcoran#	154	Turlock	56	Bakersfield-Gold	124
Clovis	83	Modesto	44	Hanford	143
Fresno-1st	92	Taft	42	Oildale	125

*-Patterson # -Van Dorsten
units in µg/m³

The meteorological synoptic analysis showed after an extended period of strong high pressure and surface and upper air stability from October 11th through November 5th, leading to building PM conditions, a trough developed across the eastern Pacific, the morning of the 6th. The trough and accompanying weak cold front slowly moved southeastward across California during the late afternoon hours. The morning surface charts depicted a surface high pressure ridge draped across Central California from the Four Corners Region to San Francisco. The 12Z surface pressure gradient was -0.6 millibars from San Francisco (SFO) to Las Vegas (LAS). A -0.6 millibars pressure gradient means light offshore flow, which results in weak disorganized wind flow across the San Joaquin Valley.

The morning temperature sounding over Fresno showed a strong inversion (stable layer) of 19 degrees Fahrenheit from the surface up to 1,500 feet as is evident in **Figure 2**. At Bakersfield the temperature sounding showed a similar strong inversion of 17 degrees Fahrenheit from the surface up to 1,500 feet. The temperature soundings on the 6th, are conducive of elevated PM levels due to low mixing depths, which keep pollutants trapped near the surface.

Figure 2: Atmospheric Temperature Profile at Fresno on November 06, 1997



Upper level charts indicated a moderate low near Vancouver Island, with a weak trough curving south-southeastward across the eastern Pacific and along the West Coast. A moderate temperature gradient at 850 MB and an upper level jet were evident over central California. Weak pressure gradients across the San Joaquin Valley strengthened slightly during the afternoon hours, with the approach of the cold front. **Table 2** shows the 24 hour daily average wind speeds at SJVAPCD air monitoring, ASOS, and CIMIS sites for November 06, 1997.

Table 2: 24 hour average wind speeds at SJVAPCD air monitoring, ASOS, and CIMIS sites for November 06, 1997.

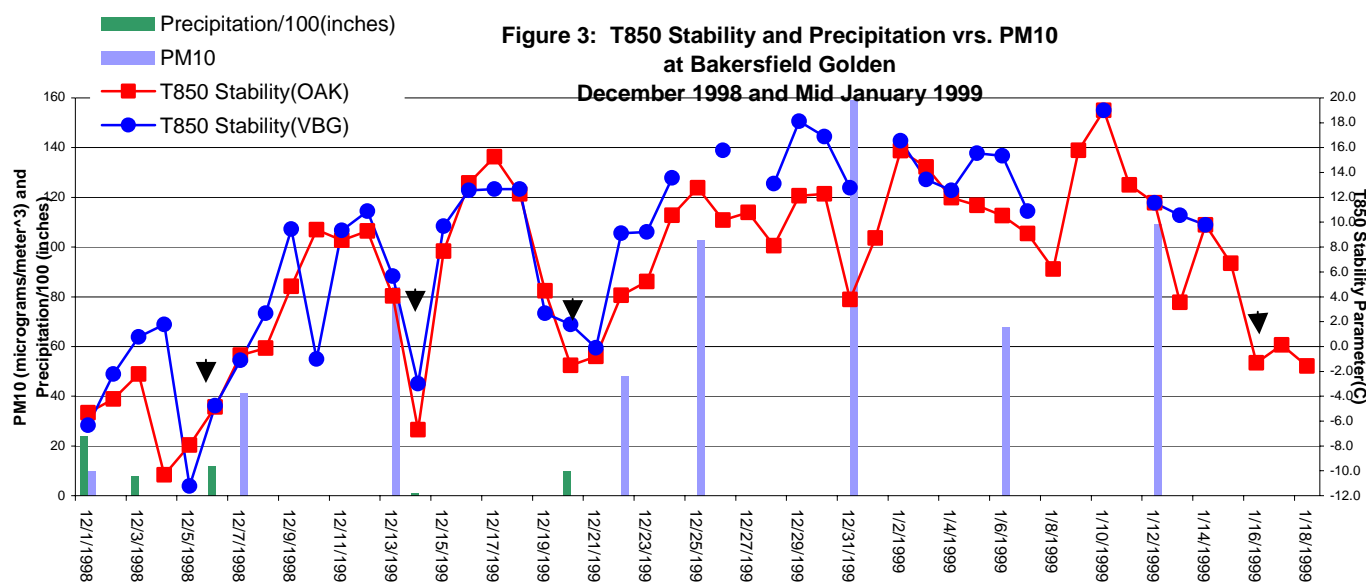
SJVAPCD Air Monitor		ASOS		CIMIS			
	WS		WS		WS		WS
	MPH		MPH		MPH		MPH
Clovis	4.8	FAT	6.8	Shafter/USDA	3.8	Famoso	3.6
Fresno Sierra Sky Park (SSP)	3.3			Firebaugh/Telles	4.6	Westlands	4.5
Corcoran	6.8			Stratford	5	Panoche	4
				Kettleman	3.8	Arvin-Edison	3.2
				Visalia/Americas	3.1	Lindcove	2.1
				Parlier	4.3	Kesterson	3.1
				Blackwells Corner	3.7	Lodi West	2.9
				Los Banos	4.5	Modesto	3.6
				Manteca	2.8	Fresno State	5.1

Due to strong stability lasting for over 28 days, PM₁₀ steadily increase region-wide until November 6th. Light disorganized wind flow, a strong morning inversion and pre-frontal stability; lead to limited dispersion conditions on the 6th causing local PM emissions in Corcoran to rapidly increase past the Federal 24-hour PM₁₀ standard to 199 µg/m³. Since other FRM Monitoring sites did not register above the Federal 24-hour PM₁₀ standard on the 6th, the Corcoran PM₁₀ measurement signifies local emission characteristics. Crop calendar activity shows that cotton/safflower and alfalfa were being prepared and harvested during early November. A weak frontal boundary moved through the region on the 7th, bringing better dispersion conditions and lowering Corcoran's PM measurement to well below the standard.

2.0 DECEMBER 31, 1998 AND JANUARY 12, 1999 EPISODE SYNOPTIC METEOROLOGICAL DISCUSSION

December 20, 1998 – January 16, 1999

The period from December 20, 1998 to January 16, 1999 was marked by 28 days of strong stability and poor atmospheric dispersion conditions. Strong high pressure over the Intermountain Region and eastern Pacific dominated the period, leading to limited dispersion. The period began with the passage of a cold, arctic front and trough on the 20th. Between the 20th and the 31st, increasing stability and poor dispersion conditions resulted in a PM₁₀ (Particulate Matter) exceedance at Bakersfield Golden and Visalia Church on the 31st, **Figure 3**.



At Bakersfield Golden and at Visalia Church, a 24-hour PM₁₀ concentration of 159 and 160 $\mu\text{g}/\text{m}^3$ were measured, respectively. **Table 3** outlines federal reference method (FRM) Daily Average Particulate Matter Measurements for sites across the San Joaquin Valley (SJV). In order to understand the variability of these measurements, an in depth examination of the synoptic pattern and surface winds and observations, and aircraft soundings leading to the episode were analyzed.

TABLE 3: Federal Reference Method (FRM) Daily Average Particulate Matter Measurements for sites across the SJV for December 31, 1998.

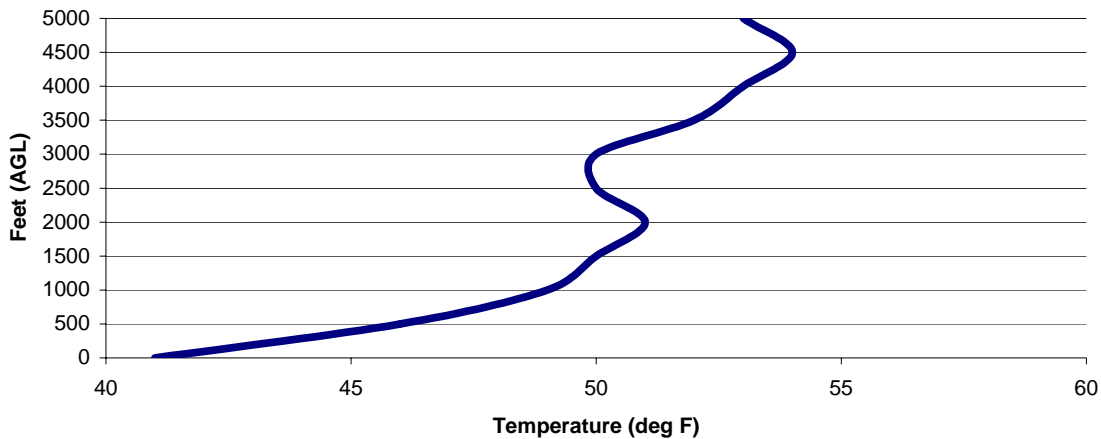
	FRM		FRM		FRM
Site Name	24-Avg.	Site Name	24-Avg.	Site Name	24-Avg.
Bakersfield-Gold	159	Turlock	87	Hanford	109
Bakersfield-CA	148	Modesto	80	Stockton#	99
Visalia	160	Taft	73	Stockton**	95
Fresno-1 st	104	Fresno-Drum	117	Corcoran*	116

*-Patterson #-Wagner, **- Hazleton
units in $\mu\text{g}/\text{m}^3$

The meteorological synoptic analysis showed after a period of strong atmospheric stability from December 20th through the 31st, a weak disturbance from the eastern Pacific approached the region. Ahead of the weak trough, stability lingered over the southern parts of the San Joaquin Valley trapping particulates within the Valley boundary layer. The afternoon surface charts on the 31st depicted a surface ridge extending southeastward across southern California from a strong high 200 NM west of Eureka. A weak cold front was draped northwestward along the Sierra Nevada Mountain range from near Bishop to Reno. The 0Z surface pressure gradient was +13.0 millibars from San Francisco (SFO) to Las Vegas (LAS), with isobars (constant surface pressure) orientated northeast to southwest. With the alignment of the isobars and the +13.0 millibars pressure gradient, this represents light to moderate north-northeasterly flow across the San Joaquin Valley. Visibilities throughout the day across the San Joaquin Valley were reporting haze.

The morning temperature aircraft sounding over Bakersfield showed multiple inversions, with a moderately strong inversion (stable layer) of 10 degrees Fahrenheit from the surface up to 2,000 feet, with a secondary inversion of 4 degrees Fahrenheit from 2,500 to 4,500 feet as is evident in **Figure 4**. The temperature sounding on the 31st, is conducive of elevated PM levels due to low mixing depths and multiple inversions, which keep pollutants trapped near the surface. At surface observations across the San Joaquin Valley, minimum temperature at Fresno was 38 degrees Fahrenheit and Bakersfield was 37 degrees Fahrenheit. These cold and poor dispersion conditions generally result in elevated concentrations of ammonia nitrate. Also on New Year's Eve (December 31), there is a great amount of residential wood combustion in the area.

Figure 4: Atmospheric Temperature Profile at Bakersfield on December 31, 1998



Upper level charts indicated a strong high 600 NM west of Santa Barbara, with a ridge building northward into the eastern Gulf of Alaska. A weak trough over the Intermountain region extended southwestward across northern California. Weak pressure gradients across the San Joaquin Valley strengthened during the afternoon hours, with the approach of the cold front.

Table 4 shows the 24 hour daily average wind speeds at SJVAPCD monitoring sites, ASOS, and CIMIS sites for December 31, 1998.

SJVAPCD Monitoring Sites		ASOS		CIMIS			
	WS		WS		WS		WS
	MPH		MPH		MPH		MPH
Clovis	5.5	Fresno	6.5	Shafter/USDA	3.0	Famoso	3.2
Fresno SSP	3.0	Bakersfield	4.0	Firebaugh/Telles	5.4	Westlands	6.5
Corcoran	4.7	Hanford	4.7	Stratford	3.8	Panoche	5.6
Edison	4.3			Kettleman	3.6	Arvin-Edison	3.0
Parlier	5.3			Visalia/Americas	2.8	Lindcove	2.1
Arvin	3.6			Parlier	4.2	Kesterson	5.0
Visalia	1.8			Blackwells Corner	3.3	Lodi West	3.9
				Los Banos	6.3	Modesto	5.6
				Manteca	4.9	Fresno State	5.2

Due to the strong stability lasting for over 11 days, PM₁₀ steadily increase region-wide until December 31st. With the approach of the weak upper level trough from northern California, moderately strong stability lingered over the southern parts of the San Joaquin Valley. This resulted in local PM₁₀ concentrations at Bakersfield-Golden and Visalia to increase above the Federal 24-hour PM₁₀ standard to 159 and 160 µg/m³, respectively. Due to the tightening pressure gradient in the northern part of the San Joaquin Valley and weak upper level trough passage, widespread San Joaquin Valley PM₁₀ exceedances did not occur on this date. The weak upper level trough traversed the entire region late on the 31st bringing slightly better dispersion conditions to the entire San Joaquin Valley on January 1st, resulting in lower PM Valley-wide.

After the weak upper level trough passage on the 31st, strong high pressure rebuilt into the region from the Great Basin and eastern Pacific, with increasing stability and poor dispersion conditions through the next exceedance date on January 12th at Oildale, **Figure 3**. At Oildale, a 24-hour PM₁₀ (Particulate Matter) concentration of 156 µg/m³ was measured.

Table 5 outlines federal reference method (FRM) Daily Average Particulate Matter Measurements for sites across the San Joaquin Valley (SJV). In order to understand the variability of these measurements, an in depth examination of the synoptic pattern and surface winds and observations, and aircraft soundings leading to the episode were analyzed.

TABLE 5: Federal Reference Method (FRM) Daily Average Particulate Matter measurements for sites across the SJV for January 12, 1999.

	FRM		FRM		FRM
Site Name	24-Avg.	Site Name	24-Avg.	Site Name	24-Avg.
Bakersfield-Gold	109	Turlock	53	Oildale	156
Bakersfield-CA	92	Modesto	48	Stockton#	39
Visalia	82	Taft	70	Stockton**	48
Fresno-1 st	85	Fresno-Drum	76	Corcoran*	51

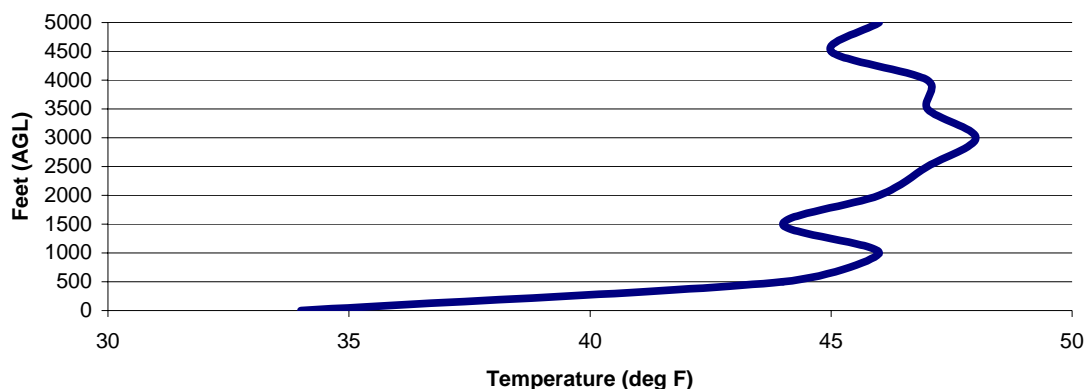
*-Patterson #-Wagner, **- Hazleton
units in µg/m³

The meteorological synoptic analysis showed after a period of strong atmospheric stability from December 31st through the 12th, a weak upper level disturbance from the eastern Pacific approached the region. Ahead of the weak trough, mid-tropospheric stability lingered over the southern parts of the San Joaquin Valley trapping particulates within the Valley boundary layer. The morning surface charts of January 12th depicted a surface ridge extending southeastward across the central San Joaquin Valley from a strong high just west of San Francisco. The 12Z surface pressure gradient was +9.0 millibars from San Francisco (SFO) to Las Vegas (LAS), with isobars (constant surface pressure) orientated northeast to southwest. With the alignment of the isobars and the +9.0 millibars pressure gradient, this represents light to moderate north-northeasterly flow across the San Joaquin Valley. Visibilities across the San Joaquin Valley in the morning reported fog turning to haze by the afternoon.

The morning temperature aircraft sounding over Bakersfield showed multiple inversions, with a moderately strong inversion (stable layer) of 12 degrees Fahrenheit from the surface up to 1,000 feet, with a secondary inversion of 4 degrees Fahrenheit from 1,500 to 3,000 feet as is evident in **Figure 5**. The temperature sounding on the January 12th, is conducive of elevated PM levels due to low mixing depths and multiple inversions, which trap pollutants near the surface. At surface observations across the San Joaquin

Valley, minimum temperature at Fresno was 30 degrees Fahrenheit and Bakersfield was 29 degrees Fahrenheit.

Figure 5: Atmospheric Temperature Profile at Bakersfield on January 12, 1999



Upper level charts indicated a moderate high well off of Baja, with a ridge draped northeastward across central California. A weak trough bends southward along the Pacific Northwest Coast from a low over the eastern Gulf of Alaska. Pressure gradients weakened slightly during the afternoon hours further decreasing boundary layer flow in the San Joaquin Valley.

Table 6 shows the 24 hour daily average wind speeds at SJVAPCD monitoring sites, ASOS, and CIMIS sites for January 12, 1999.

SJVAPCD Monitoring Sites		ASOS		CIMIS			
	WS		WS		WS		WS
	MPH		MPH		MPH		MPH
Clovis	2.6	Fresno	1.8	Shafter/USDA	2.6	Famoso	2.7
Fresno SSP	1.5	Bakersfield	4.8	Firebaugh/Telles	2.5	Westlands	3.1
Corcoran	3.0	Hanford	1.3	Stratford	2.9	Panoche	3.1
Edison	4.0			Kettleman	3.2	Arvin-Edison	2.9
Parlier	2.9			Visalia/Americas	2.4	Lindcove	2.0
Arvin	3.3			Parlier	2.5	Kesterson	2.4
Visalia	1.4			Blackwells Corner	2.5	Lodi West	2.7
				Los Banos	2.9	Modesto	4.5
				Manteca	4.0	Fresno State	2.7

Due to the strong stability lasting for over 24 days, PM₁₀ steadily increase region wide until January 12th. With the approach of the weak trough from northern California, moderately strong stability lingered over the southern parts of the San Joaquin Valley leading to local PM concentrations at Oildale increasing above the Federal 24-hour PM₁₀ standard at 156 µg/m³. Due to the increasing dispersion aloft from the weak upper level trough passage, widespread San Joaquin Valley PM₁₀ exceedances did not occur on this date; thus the exceedance at Oildale was representative of local emissions driving the particulate measurement. Weak upper level disturbances

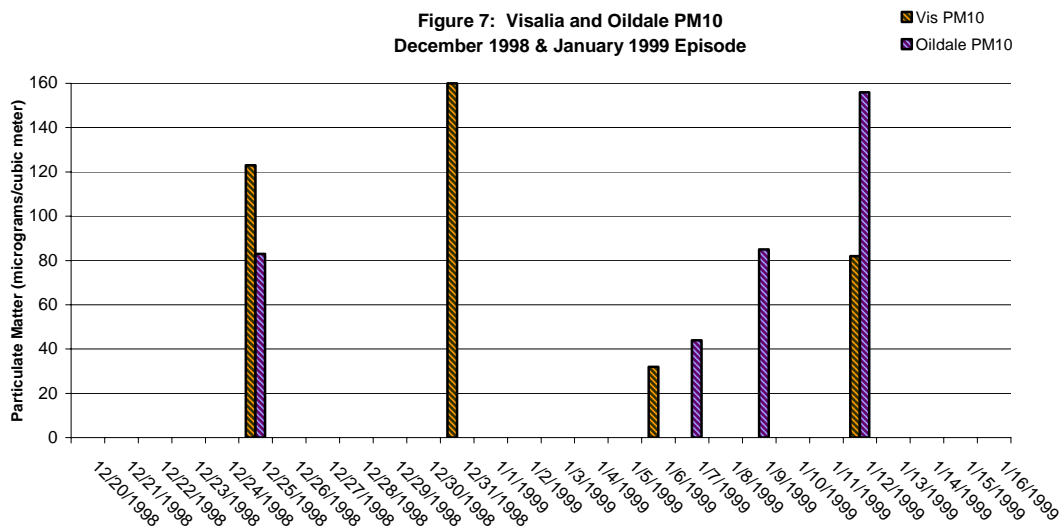
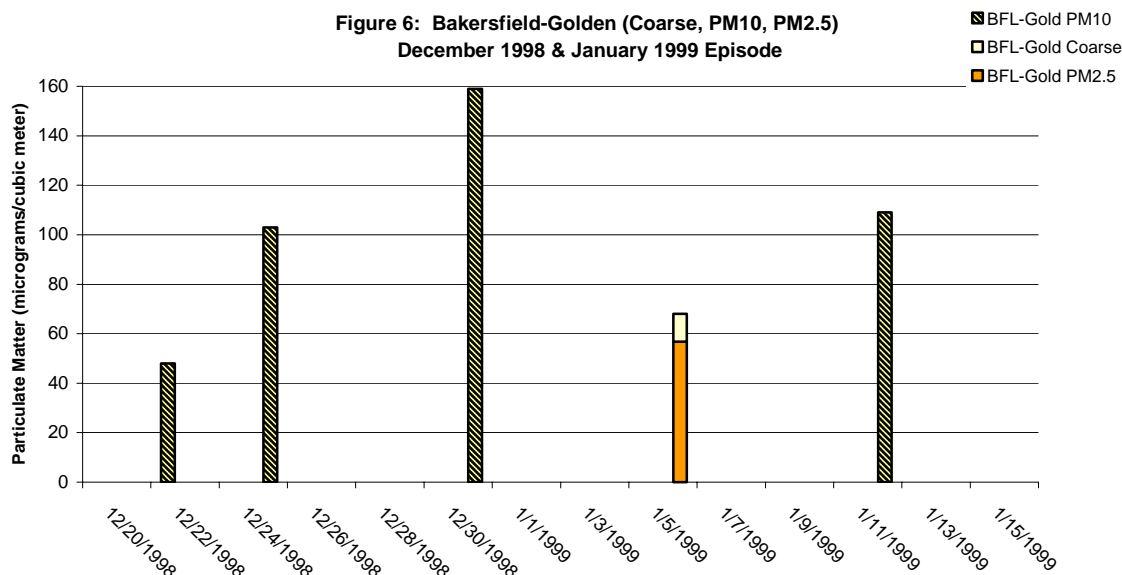
continued to traverse the region through January 16th, bringing better dispersion conditions and an end to the PM episode that recorded exceedances at Bakersfield and Visalia on December 31st, 1998 and Oildale on January 12th, 1999.

3.0 INTEGRATED ANALYSIS OF ATMOSPHERIC CHEMISTRY AND METEOROLOGY DURING THE JANUARY 12, 1999 EPISODE

The January 1999 particulate episode was characterized by a prolonged period (four weeks) of strong stability and light wind flow, which resulted in poor atmospheric dispersion conditions across the San Joaquin Valley. Coarse and fine particulates accumulated during the period, leading to two separate exceedance days on Thursday, December 31, 1998 and Tuesday, January 12, 1999. A weak upper level disturbance moved over the region on December 31, 1998, dividing the episode into two separate periods. Concentrations were dominated by the fine particulates ($PM_{2.5}$) of ammonia nitrate and sulfate and were most prevalent in the central and southern San Joaquin Valley. The first period was marked by strong stability and light wind flow, which led to exceedances at Bakersfield-Golden with a PM_{10} concentration of $159 \mu g/m^3$ and Visalia-Church with a PM_{10} concentration of $160 \mu g/m^3$ on December 31, 1998 (**Figure 6 & 7**). PM_{10} concentrations at other central and southern Valley locations were much lower, below $115 \mu g/m^3$, with the exception of nearby Bakersfield-California, which measured a PM_{10} concentration of $148 \mu g/m^3$. However, the December 1998 exceedances are included in the discussion to provide context to the episode. After the weak trough passage on December 31, 1998 both primary and secondary pollutants accumulated once again leading to an exceedance of the 24-hour standard at Oildale-Manor, with a PM_{10} concentration of $156 \mu g/m^3$ on January 12, 1999 (**Figure 7**). The next highest PM_{10} concentration measured was at Bakersfield-Golden with $109 \mu g/m^3$. PM_{10} concentrations at other central and southern Valley locations were below $90 \mu g/m^3$. During both periods, strong high pressure at the surface and aloft resulted in limited afternoon mixing and light offshore wind flow. Cool damp mornings and strong stability contributed to the formation of nitrates and sulfates during the episode. Chemical composition and meteorological data around December 31, 1998 and January 12, 1999, were evaluated and analyzed to identify the characteristics and uniqueness of the exceedances at Bakersfield-Golden, Visalia-Church, and Oildale-Manor.

The December 31, 1998 exceedances are not considered for compliance with the current Particulate Matter State Implementation Plan (SIP) because the exceedances fall outside of the three year required window. Although PM_{10} sampling is not conducted daily, information from changes in the meteorological conditions suggest that the highest PM_{10} concentration was not captured on the sampled day (December 31, 1998). Daily meteorological conditions suggested that the highest PM_{10} concentrations may have occurred on December 29th, when stability was the strongest. With the lack of chemical data for Bakersfield-Golden, similarities in trends from other sites were analyzed in order to conclude which chemical components were responsible for the exceedance. The analysis shows that the exceedance was driven by high concentrations of ammonium nitrate and sulfate that comprised 74% of the PM_{10} mass at nearby Bakersfield-California. At Visalia, the nitrate and sulfate chemical component of the PM_{10} sample was slightly higher compared to Bakersfield-California. These have accounted for the slight differences in the PM_{10} mass between the two sites. The other major chemical components of the sample were 21% total carbon and 13% geological of the PM_{10} mass. The size fraction data across the Valley indicated that most of the

PM₁₀ was in the PM_{2.5} fraction, with an average PM_{2.5}/PM₁₀ mass ratio of greater than 0.8.



This was further supported by the high PM_{2.5} concentrations that reached 122 µg/m³ at nearby Bakersfield-California accounting for 81 percent of the PM₁₀ mass and at Visalia of 139 µg/m³ accounting for 83 percent of the PM₁₀ mass.

The concentration of coarse material may have been higher at the Bakersfield-Golden as is indicated by nearby Bakersfield-California and Visalia having the highest geological component of 13 µg/m³ compared to other Valley locations. Urban geological may have influenced the sample at Bakersfield-Golden and Visalia. Light afternoon mixing and wind flow may have allowed some transported contribution from agricultural burning in Merced, Stanislaus, and San Joaquin Counties on December 31st. However a no burn day across the rest of the Valley, indicates that stagnant

conditions favored a larger influence from local emissions. Burn variances and noncompliant agricultural burns may have contributed to a small portion of the samples. Overnight minimum temperatures in the mid to upper 30's suggest that residential wood burning may have been a significant source of PM₁₀. The potential of increased residential wood burning on New Year's Eve, may have led to increased concentrations of total carbon in the samples. Analysis of PM₁₀ and PM_{2.5} concentrations showed that meteorological conditions led to the pollution buildup. Ammonium nitrate and sulfates, carbon, and geological material increased prior to the exceedances on December 31, 1998 and then later on January 12, 1999.

Meteorologically, dispersion worsened and particulate formation conditions strengthened from December 20th to the 29th. However, on December 31st, the exceedance day, dispersion conditions began to improve under decreasing stability. After the passage of a cold front on December 20th, which brought 0.10 inches of rainfall to Bakersfield, moisture was available for atmospheric chemistry reactions. Humidity measurements of 85 – 100 % in the morning across the Valley Floor showed a moist atmosphere with light fog and haze being reported. These cool damp mornings and strong stability favored the formation of nitrates and sulfates. Synoptically, the eastern Pacific high remained strong through December 29th and gradually weakened through December 31st. The high rebuilt over the region on January 1st, keeping a lid over the San Joaquin Valley trapping pollutants within the Valley boundary layer through January 16, 1999.

With a strong lid in place and maximum high temperatures on December 31, 1998 in the mid to upper 50's, the afternoon hours were marked by limited mixing, resulting in increasing particulate conditions. Mixing heights at Fresno remained below 500 feet under a strong inversion for 14 hours on December 31, 1998 breaking out by 10:00 AM and reforming shortly after 7:00 P.M. During the afternoon hours, there were higher mixing depths (maximum mixing depth of 4,500 feet), but the bulk of the day had limited to marginal mixing. Maximum temperatures for the December 1998 episode were slightly above normal, further illustrating the intensity of the high pressure system that was controlling the region's weather. Satellite imagery depicted extensive moisture (high and mid-level cloudiness) across the region on the 31st, resulting in slightly lower levels of solar radiation intensity. Along with the lower solar radiation intensities due to the low sun angle and limited daylight hours, the atmospheric chemistry reactions may have favored the secondary particulate forming regime.

Chemical composition and meteorological data showed with limited mixing depths and light and disorganized wind flow, these conditions resulted in minimal transport and dispersion of pollutants. Both primary and secondary pollutants from local emissions around Bakersfield-Golden and Visalia accumulated resulting in the exceedance of the 24-hour PM₁₀ standard on December 31, 1998.

Meteorological stability between December 31, 1998 and January 10, 1999 remained strong leading to moderate to elevated particulate conditions continuing across the San Joaquin Valley. Weak disturbances were moving through northern California prior to

the exceedance day, inhibiting widespread exceedance levels. The strong ridge that dominated the region's weather finally began to breakdown on January 10, 1999, with decreasing stability. However, both primary and secondary pollutants from local emissions around Oildale-Manor accumulated resulting in an exceedance of the 24-hour PM_{10} standard on January 12, 1999 (**Figure 7**); with nearby Bakersfield Golden recording a peak PM_{10} concentration on the exceedance day of $109 \mu\text{g}/\text{m}^3$. Additionally, later on January 14, 1999 $PM_{2.5}$ monitoring at nearby Bakersfield California showed peak concentrations of $109 \mu\text{g}/\text{m}^3$. Concentrations were dominated by the fine particulates ($PM_{2.5}$) of ammonia nitrate and sulfate and were most prevalent in the central and southern San Joaquin Valley. During the period, strong high pressure at the surface and aloft resulted in limited afternoon mixing and light offshore flow. Moisture from recent rainfall was available and strong morning stability contributed to the formation of nitrates and sulfates during the episode. These meteorological conditions led to elevated particulate concentrations. Chemical composition and meteorological data around January 12, 1999, was evaluated and analyzed to identify the characteristics and uniqueness of the exceedance at Oildale-Manor.

Although PM_{10} sampling is not conducted daily, information from more frequent $PM_{2.5}$ sampling combined with an assessment of changes in the meteorological conditions suggest that the highest PM_{10} concentration was not captured on the sampled day. Analysis of daily meteorological conditions suggested that the highest PM_{10} concentrations may have occurred on January 10th, when stability was the strongest. Chemical data from Oildale-Manor showed that the exceedance was driven by high concentrations of ammonium nitrate and sulfate comprising about 57 % of the PM_{10} mass. The size fraction data across the Valley indicated that most of the PM_{10} was in the $PM_{2.5}$ fraction, with an average $PM_{2.5}/PM_{10}$ mass ratio of greater than 0.8. This was further supported by the high $PM_{2.5}$ concentrations that reached $84 \mu\text{g}/\text{m}^3$ at nearby Bakersfield-California.

The concentration of coarse material was minimal on the exceedance day, indicating that the majority of the sample was comprised of fine particulates. Agricultural burning may not have contributed as a potential source of PM on the exceedance day, because January 8 through January 12, 1999 were declared No Burn Day's District-wide. However, burn variances and noncompliant agricultural burns may have contributed to a small portion of the samples. Overnight minimum temperatures in the upper 20's to low 30's suggested that residential wood burning may have been a significant source of PM_{10} . Residential wood burning may have been a potential source of carbon. Concentrations of total carbon were measured at three sites in the Valley and ranged from $12 \mu\text{g}/\text{m}^3$ at Modesto-14th Street to $27 \mu\text{g}/\text{m}^3$ at Fresno-1st. PM_{10} and $PM_{2.5}$ concentrations showed that meteorological conditions led to the exceedance at Oildale-Manor. Local sources of ammonia nitrate and sulfate coupled with moderately strong atmospheric stability resulted in the high PM_{10} recorded at the exceedance site.

Meteorologically, dispersion conditions began to improve slightly a few days prior to the January 12, 1999 exceedance. After the passage of a weak cold front on December 20th, which brought 0.10 inches of rainfall to Bakersfield, some moisture was available

for atmospheric chemistry reactions. Humidity measurements of 85-95% in the morning across the Valley Floor showed a moist atmosphere, with light to dense fog and haze being reported. These cool damp mornings and strong stability favored the formation of nitrates and sulfates. Synoptically, the eastern Pacific high began to break down on the 10th, but stability remained strong across the region until the exceedance day. The high kept a strong lid in place over the Valley, trapping pollutants within the San Joaquin Valley boundary layer.

With a strong lid in place and maximum high temperatures in the low to mid 50's, the afternoon hours were marked by limited mixing, resulting in elevated particulate conditions. Mixing heights at Fresno remained below 500 feet for 21 hours on January 12th, breaking out by 3 P.M. and reforming shortly after 5:00 P.M. During the afternoon hours, there were higher mixing depths (maximum mixing depth of 1,000 feet), but the bulk of the day had limited mixing. Light to dense fog was reported at the Valley surface during the morning hours of January 12th, resulting in lower solar radiation intensities. Along with lower solar radiation intensities due to the low sun angle and decreasing daylight hours, the atmospheric chemistry reactions may have favored the secondary particulate forming regime.

Chemical composition and meteorological data showed limited mixing depths and light and disorganized wind flow resulted in minimal transport and dispersion of pollutants. A major cause of the increase in PM₁₀ at Oildale prior to January 12 appears to be from nitrates, which was more than double that concentration measured at Bakersfield California. This would suggest that something very localized or unique was occurring around Oildale that went beyond what was happening in other parts of the Valley. Both primary and secondary pollutants from local emissions around Oildale-Manor accumulated resulting in the exceedance of the 24-hour PM₁₀ standard on January 12, 1999.

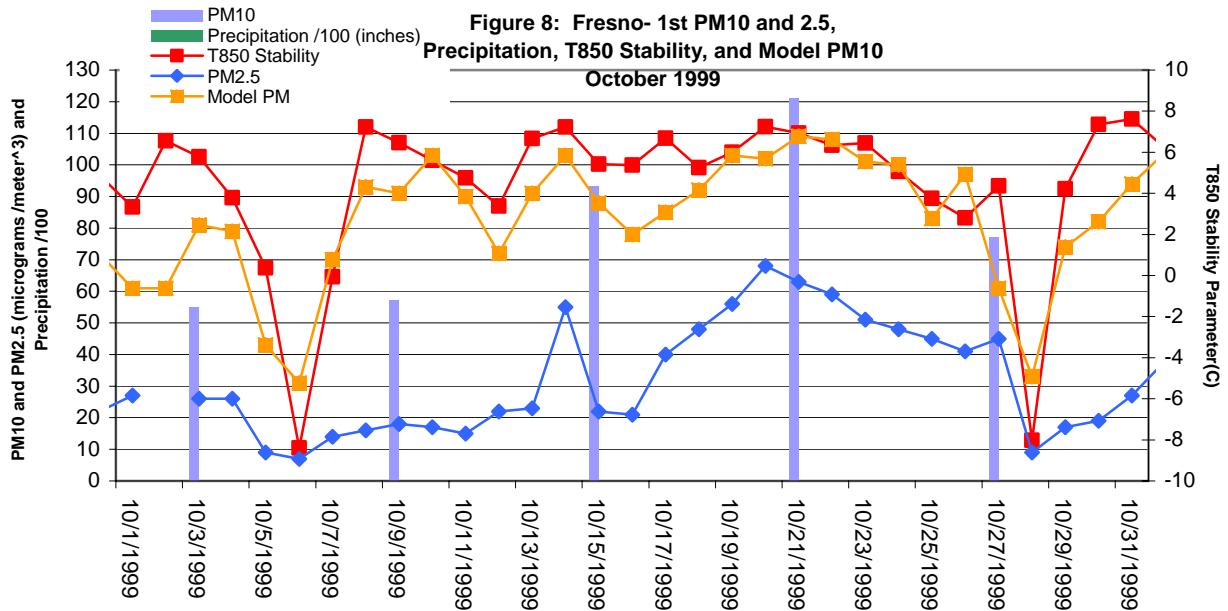
4.0 OCTOBER 21, 1999 EPISODE SYNOPTIC METEOROLOGICAL DISCUSSION

October 07-October 28, 1999

Throughout the San Joaquin Valley on October 21, 1999, several sites exceeded the Federal 24-hour PM₁₀ Standard. These sites included: Fresno-Drummond Street at 162 µg/m³, Corcoran-Patterson Avenue at 174 µg/m³, and Turlock – S Minaret Street at 157 µg/m³. In order to better understand the region wide occurrence of Particulate Material (PM) during this event, the synoptic meteorology, stability parameters, satellite imagery, atmospheric temperature profiles, and solar intensity measurements were investigated to determine the cause for the exceedances, which occurred on October 21, 1999.

Strong high pressure aloft and at the surface dominated the region's weather throughout the month of October 1999. This month was characterized by above normal temperatures (+3.4 °F) and below normal rainfall (-0.53 inches). The October 21, 1999 episode was preceded by deteriorating stability conditions after the passage of a weak trough into the Pacific Northwest on the 5th. **Figure 8** shows precipitation, PM_{2.5}, PM₁₀, Model PM, and stability parameters for the October 1999 episode at the Fresno-1st site.

Figure 8 also shows that the October 21st, 1999, episode was marked by a long period (21 days) of stable weather, with an average 500 MB height of 5,820 meters and 850 MB temperature of +16.4°C. According to Hackney et. al., both the 500 MB height and 850 MB temperature were highly suggestive of a PM₁₀ episode occurring. The San Joaquin Valley Air District uses regression equations to forecast PM₁₀. As is evident in **Figure 8**, Modeled PM₁₀ tracked closely with both the measured PM₁₀ and meteorological parameters. PM₁₀/PM_{2.5} ratios showed an increasing amount of fine particulates within the sample, representing a change from a more typical coarse dominate fall regime to an increasingly dominated fine particulate regime of late November as is illustrated in **Figure 8**.

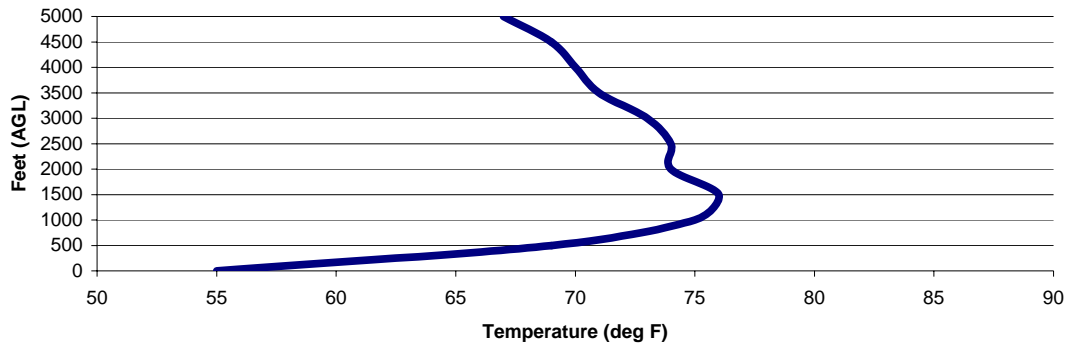


Next, winds speeds were analyzed during the exceedance date across the Valley. For example, at the Clovis monitoring site the 24 hour average wind speed was less than 2.2 knots (2.4 miles per hour). Since there was a strong high positioned across the region, the winds were calm in the morning becoming light thermally driven during the afternoon, resulting in minimal transport and dispersion. These weak winds are indicative of historical PM₁₀ episodes.

These strong stable conditions continued through the 24th until the ridge began to breakdown and move eastward on the 25th. A cool, dry trough moved into the Pacific Northwest on the 28th, bringing good dispersion conditions, moderate to high boundary layer mixing heights and an end to the October 1999 episode.

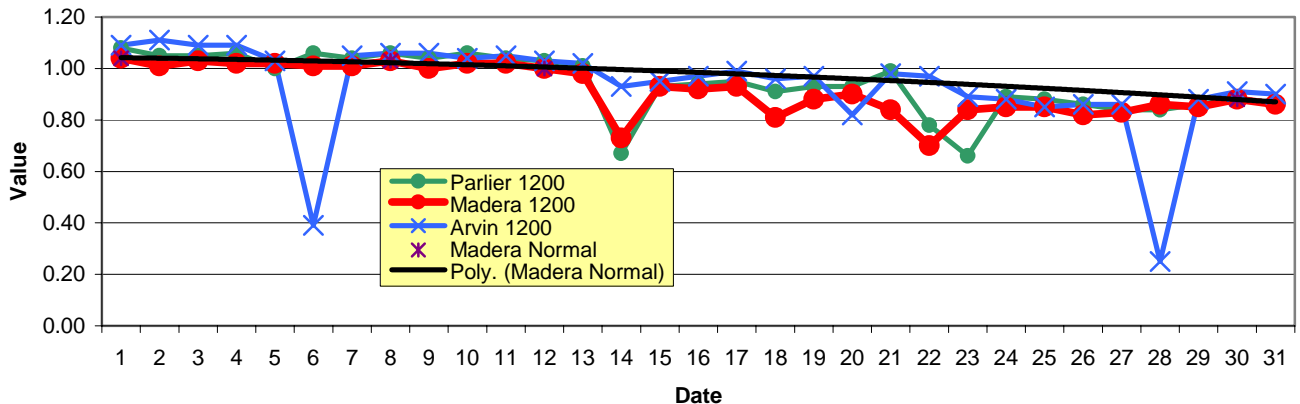
The morning temperature profile from several sites were also investigated to determine the inversion strength and potential mixing depth. As is evident in **figure 9**, the morning temperature profile measured at 4:00 a.m. from Fresno depicts a very strong inversion of 21 degrees Fahrenheit from the surface up to 1,500 feet, turning slightly isothermal (constant temperature) up to 3,000 feet. This type of strong trapping inversion was also evident in Sacramento (22 degrees Fahrenheit from the surface up to 1,500 feet) and Bakersfield (12 degrees Fahrenheit from the surface up to 2,000 feet). The strong morning inversions present across the region coupled with very light wind flow, trapped most pollutants near the surface in a very low mix layer throughout most of the day resulting in the elevated PM₁₀ measurements.

Figure 9: Atmospheric Temperature Profile at Fresno on October 21, 1999



Another meteorological parameter investigated was solar intensity. Solar intensity for the month of October was also analyzed to determine if particulate material aloft or at the surface was lowering the solar radiation input, which drives both photochemical reactions and particulate matter formation. As is evident in **figure 10**, three sites were analyzed; Madera, Parlier, and Arvin. It is evident especially with the solar intensity plot for Madera, that particulate matter was present over Madera, thus reducing the solar intensity measurement to below normal levels. This in effect, would change the atmospheric chemistry reactions from a more photochemistry-ozone forming regime to a more particulate regime that occurs during late November.

Figure 10: October 1999 Solar Intensity

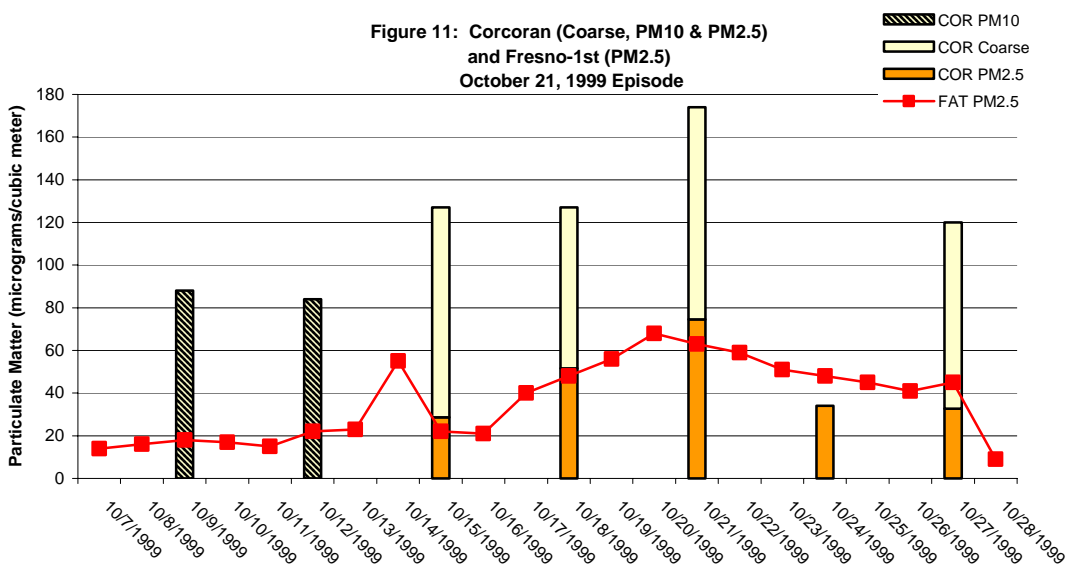


Satellite imagery analysis showed a weak low well off of Baja, drawing upper level moisture across the region. Varying amounts of high cloudiness were evident preceding the peak episode day and occurring through the 22nd. These clouds coupled with particulate aloft, drove the photochemistry reactions in the atmosphere into a fine particulate forming regime rather than an ozone forming regime.

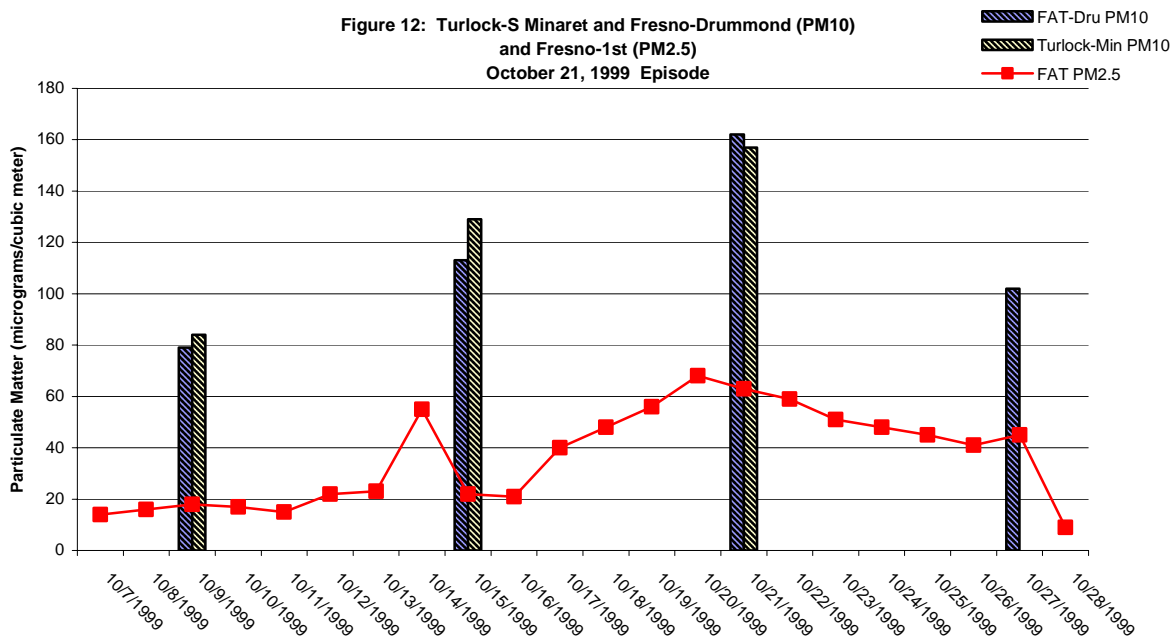
Upon investigating the synoptic meteorology, stability parameters, atmospheric temperature profiles, and satellite imagery, these all are indicative of a widespread PM₁₀ event, occurring in the San Joaquin Valley on October 21, 1999.

5.0 INTEGRATED ANALYSIS OF ATMOSPHERIC CHEMISTRY AND METEOROLOGY DURING THE OCTOBER 21, 1999 EPISODE

The October 21, 1999 particulate episode was characterized by a prolonged period (three weeks) of strong stability and light wind flow, which resulted in poor atmospheric dispersion conditions across the San Joaquin Valley. Coarse and fine particulates accumulated during the period, leading to an exceedance of the 24-hour PM_{10} standard at three monitoring sites on October 21, 1999. Concentrations were dominated by geological particulates (PM_{10}), with significant contributions from fine particulates of ammonium nitrate and sulfate and total carbon and were most prevalent in the northern and central portions of the Valley and slightly lower in the southern portion (Kern County). The highest PM_{10} concentration of $174 \mu\text{g}/\text{m}^3$ was measured at Corcoran-Patterson (**Figure 11**). The second and third highest PM_{10} concentration of 162 and $157 \mu\text{g}/\text{m}^3$ were measured at Fresno-Drummond and Turlock, respectively (**Figure 12**). During the period, strong high pressure at the surface and aloft resulted in limited afternoon mixing and light offshore wind flow. Cool damp mornings and warm dry afternoons contributed to the geologic contribution, as well as nitrate and sulfate formation during the episode. A combination of these particulate species and poor dispersion conditions elevated particulate concentrations. Chemical composition and meteorological data around October 21, 1999, was evaluated and analyzed to identify the characteristics and uniqueness of the exceedances at Corcoran-Patterson, Fresno-Drummond, and Turlock- S Minaret.



Although PM_{10} sampling is not conducted daily, information from more frequent $PM_{2.5}$ sampling combined with an assessment of changes in the meteorological conditions suggest that the highest PM_{10} concentration was not captured on the sampled day. Daily $PM_{2.5}$ sampling and meteorological conditions suggested that the highest PM_{10} concentrations may have occurred on October 20th, when Fresno 1st measured a peak $PM_{2.5}$ concentration of $68 \mu\text{g}/\text{m}^3$. Chemical composition data indicated that geological material was the single largest component of the PM_{10} during this episode.



While geologic dominated the PM₁₀ mass, increases in other components (carbon, and ammonium nitrate and sulfate) were what drove the increase in concentration to over the PM₁₀ Standard. It appears that the exceedance was driven by high concentrations of geologic comprising about 50 to 60 % of the PM₁₀ mass. The other components of the samples were composed of 15 to 25 % ammonium nitrate and sulfate and 10 to 20 % total carbon of the PM₁₀ mass. The size fraction data across the Valley indicated that most of the PM₁₀ was in the PM₁₀ fraction, with an average PM_{2.5}/PM₁₀ mass ratio greater than 0.35. This was further supported by the high coarse concentrations that reached 100 µg/m³ at Corcoran-Patterson, accounting for 57 percent of the PM₁₀ mass (**Figure 11**).

The concentration of coarse material may have been elevated due to the lack of precipitation since June 2, 1999 contributing to the high geologic fraction. Dry conditions and low soil moisture content, resulted in higher dust emission activity from agricultural land preparing and harvesting and urban geological activities. Agricultural burning probably did not contribute to PM on the exceedance day, because October 17 through October 21, 1999 were declared No Burn Day's District-wide. However, burn variances and noncompliant agricultural burns may have contributed to a small portion of the samples. Overnight temperatures in the mid 50's suggested that residential wood burning was not likely a potential source of PM₁₀. PM₁₀ and PM_{2.5} concentrations showed that meteorological conditions led to the pollution buildup.

Meteorologically, dispersion worsened and particulate formation conditions strengthened from October 7th to the 20th. However, on October 21st, the day of the exceedance, dispersion conditions began to slightly improve under weakening stability. The lack of precipitation since June 2nd, 1999 may have contributed to the geologic fraction. Dry conditions and low soil moisture content, resulted in higher dust emission activity. Humidity measurements of 60-80% in the morning across the Valley Floor

showed a dry to moist atmosphere, with no fog present. The cool damp mornings and strong stability favored some formation of nitrate and sulfate particulates. The eastern Pacific high built over the San Joaquin Valley on October 7th and dominated the region's weather through the 20th. The high began to slowly break down on the 21st, but remained strong, trapping pollutants within the San Joaquin Valley boundary layer.

With a strong lid in place aloft and maximum high temperatures in the mid-80's, the afternoon hours were marked by limited mixing, resulting in elevated particulate conditions. Mixing heights at Fresno remained below 500 feet under a strong inversion for 16 hours on the 21st, breaking out by 12:00 P.M. and reforming by 5:00 P.M. During the afternoon hours, there were higher mixing depths (maximum mixing depth near 5,000 feet), but the bulk of the day had limited mixing. Maximum and minimum temperatures for the October 1999 were above normal, further illustrating the intensity of the high pressure system that was controlling the region's weather. Partly cloudy skies and hazy conditions reported at the Valley surface on October 21st, resulted in lower levels of solar radiation intensities. Along with several wildfires to the north and along the California Coast and a major tire fire at Westley earlier in the month, particulate loading aloft may have further decreased solar radiation intensity measurements across the Valley Floor. The reduction of solar radiation intensity may have led to lower mixing depths and increased atmospheric chemistry reactions forming particulates. Ambient air samples around the Westley tire fire site on the 21st confirmed minimal hydrocarbon and carbon monoxide concentrations, showing little if any impact around the tire fire. However, visual observations of the tire fire plume behavior indicated transport and mixing well down-wind of the site, which may have fumigated and impacted other parts of the San Joaquin Valley.

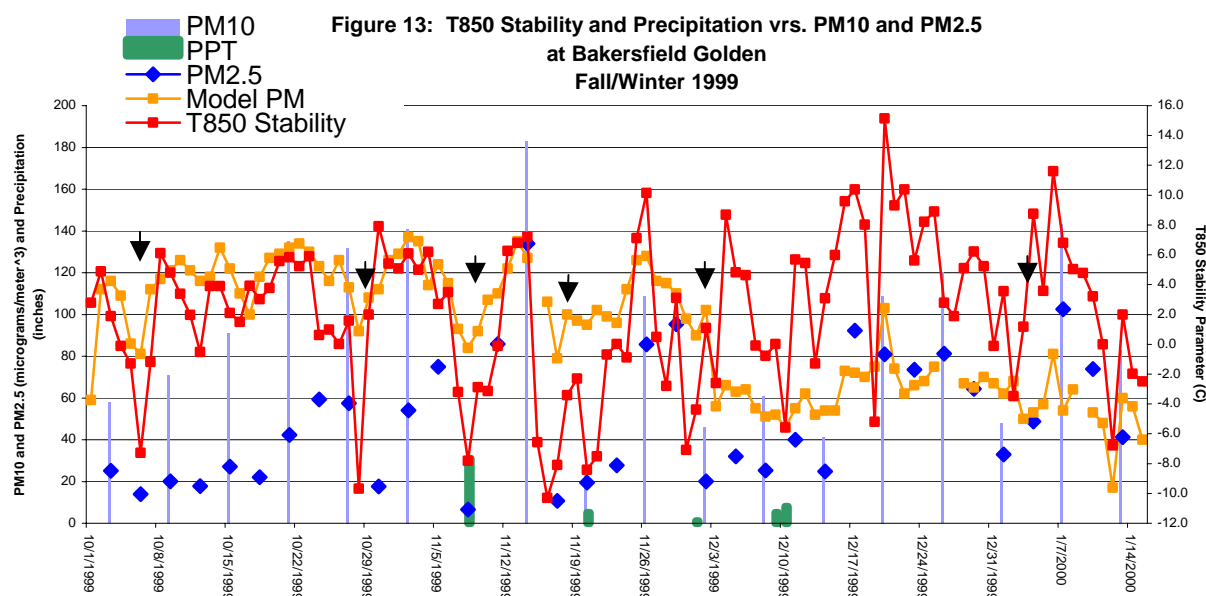
With reduced solar radiation, the atmospheric chemistry reactions may have changed from the ozone-forming regime of mid-October to the secondary particulate regime that occurs during late November. The eight-hour average ozone measurements on October 20th showed one exceedance of the Federal standard at Clovis of 87 ppb. The following day a significant change in the photochemical reactions occurred in the atmosphere, with the eight-hour average ozone measurements dropping to well below the standard at Clovis to 73 ppb. Atmospheric stability remained rather strong and persistent on the 21st, however, solar radiation measurements Valley-wide showed reduced intensities. The change in the ozone measurements across the San Joaquin Valley may be illustrative of the atmospheric chemistry reactions shifting from an ozone to a particulate-forming regime. The change in the atmospheric chemistry reactions may have led to an increase in nitrate and sulfate in the PM samples that were measured on October 21st compared to the 15th. Increasing accumulations of carbon can be contributed to the deteriorating dispersion conditions experienced during the days preceding October 21st. It does not appear that any one source of carbon was a dominant contributor. Under the strong lid, wind flow was light and disorganized, leading to minimal transport and dispersion. As a result, local emissions may have contributed to the exceedances experienced on the 21st.

Chemical composition and meteorological data showed limited mixing depths and light and disorganized wind flow resulted in minimal transport and dispersion of pollutants. Solar radiation measurements showed lower levels of intensities on the 21st compared to the 20th, resulting in an anomalous shift of the atmospheric chemistry reactions from an ozone to a particulate-forming regime. Both primary and secondary pollutants from local emissions around Corcoran-Patterson, Fresno-Drummond, and Turlock- S Minaret accumulated, resulting in the exceedance of the 24-hour PM₁₀ standard at three monitoring sites on October 21, 1999.

6.0 NOVEMBER 14, 1999 EPISODE SYNOPTIC METEOROLOGICAL DISCUSSION

November 8 – November 17, 1999

After the trough passage on November 8th, which brought 0.31 inches of rainfall at Bakersfield, strong surface high pressure from the Intermountain Region and a 500 MB ridge from northwestern Mexico built into the region. These conditions lead to increasing stability and poor dispersion conditions through the exceedance date on November 14th, **Figure 13**.



At Bakersfield, Golden, a 24-hour PM₁₀ (Particulate Matter) concentration of 183 µg/m³ was measured on the 14th. **Table 7** outlines federal reference method (FRM) Daily Average Particulate Matter Measurements for sites across the San Joaquin Valley (SJV). In order to understand the variability of these measurements, an in depth examination of the synoptic pattern and surface winds and observations, and aircraft soundings leading to the episode were analyzed.

TABLE 7: Federal Reference Method (FRM) Daily Average Particulate Matter Measurements for sites across the SJV for November 14, 1999.

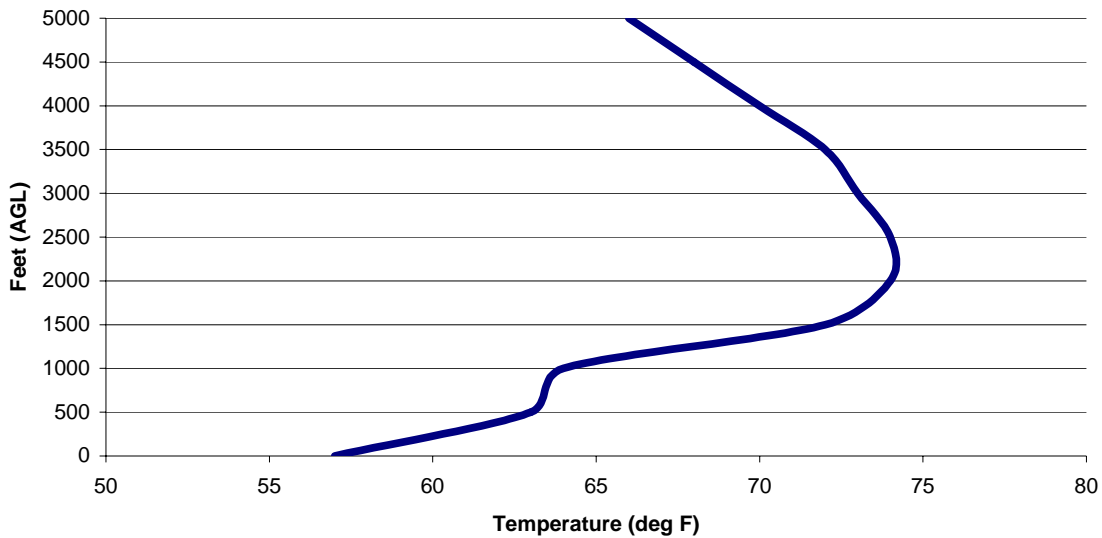
	FRM			FRM			FRM	
Site Name	24-Avg.		Site Name	24-Avg.		Site Name	24-Avg.	
	10	2.5		10	2.5		10	2.5
Bakersfield-Gold	183	134	Modesto	67	70	Hanford	138	
Bakersfield-CA	138	115	Merced-M St.	75	67	Stockton**	60	55
Visalia	137	121	Taft	70		Clovis	108	98
Fresno-1 st	124	115	Fresno-Drum	130		Corcoran*	142	114

*-Patterson **- Hazleton
units in $\mu\text{g}/\text{m}^3$

The meteorological synoptic analysis showed after a period of moderately strong atmospheric stability from November 8th through the 17th, an upper level closed low from the eastern Pacific approached the region. Ahead of the closed low, strong stability occurred over the San Joaquin Valley trapping particulates within the Valley boundary layer. The morning surface charts on the 14th depicted a surface high pressure ridge draped across Central California from the Great Basin to San Francisco. The 12Z surface pressure gradient was -3.6 millibars from San Francisco to Las Vegas (SFO-LAS), with isobars (constant surface pressure) orientated northwest to southeast. With the alignment of the isobars and the -3.6 millibars pressure gradient, light offshore flow resulted in weak disorganized wind flow across the San Joaquin Valley. Visibilities throughout the day across the San Joaquin Valley were reporting haze.

The morning temperature aircraft sounding over Bakersfield showed a strong inversion (stable layer) of 17 degrees Fahrenheit from the surface up to 2,000 feet as is evident in **Figure 14**. At Fresno the temperature sounding showed a similar strong inversion of 24 degrees Fahrenheit from the surface up to 2,000 feet. The temperature soundings on the 14th are conducive of elevated PM levels due to low mixing depths, which keep pollutants trapped near the surface. At surface observations across the San Joaquin Valley, minimum temperature at Fresno was 48 degrees Fahrenheit and Bakersfield was 49 degrees Fahrenheit.

Figure 14: Atmospheric Temperature Profile at Bakersfield on November 14, 1999



Upper level charts indicated a strong high over the Four Corners Region, with a ridge extending westward across California. At 850 MB a temperature ridge built northwestward across the San Joaquin Valley from southern California. A closed low was positioned 600 NM west of Santa Barbara. The pressure gradient across the San Joaquin Valley remained weak during the day leading to light and disorganized wind flow across the region. **Table 8** shows the 24 hour daily average wind speeds at SJVAPCD air monitoring, ASOS, and CIMIS sites for November 14, 1999. The 24 hour daily average wind speeds across the Valley floor were conducive to elevated PM readings over the central and southern parts of the San Joaquin Valley.

Table 8 shows the 24 hour daily average wind speeds at SJVAPCD monitoring, ASOS, and CIMIS sites for November 14, 1999.

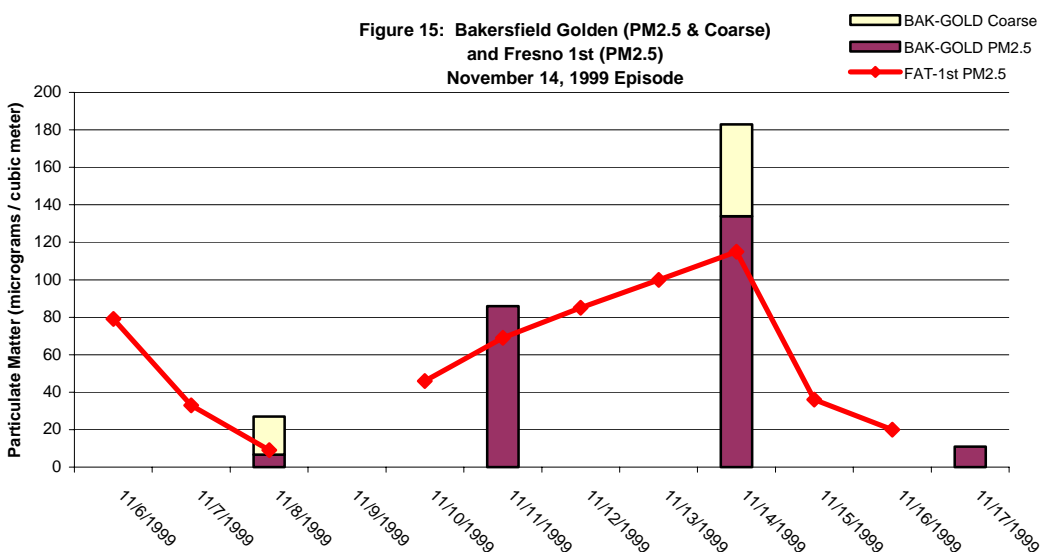
SJVAPCD Monitoring Sites		ASOS		CIMIS			
	WS		WS		WS		WS
	MPH		MPH		MPH		MPH
Clovis	3.9	Fresno	4.1	Shafter/USDA	3.5	Famoso	3.1
Fresno SSP	2.0	Bakersfield	6.1	Firebaugh/Telles	3.5	Westlands	3.9
Corcoran	3.0	Hanford	2.9	Stratford	3.0	Panoche	4.5
Edison	2.3			Kettleman	4.1	Arvin-Edison	3.2
Parlier	3.6			Visalia/Americas	2.4	Lindcove	1.9
Arvin	2.1			Parlier	3.0	Kesterson	3.2
Visalia	1.4			Blackwells Corner	5.4	Fresno State	3.4
				Los Banos	4.2	Modesto	3.1
				Manteca	2.9		

Due to the strong stability lasting for over 9 days, PM₁₀ steadily increased region-wide until November 14th, 1999. Light disorganized wind flow, a strong morning inversion, limited mixing depths, and strong stability aloft; lead to limited dispersion conditions on the 14th causing local PM emissions in Bakersfield Golden to increase past the Federal 24-hour PM₁₀ standard to 183 µg/m³. Since the other FRM Monitoring sites did not register above the Federal 24-hour PM₁₀ standard on the 14th, the Bakersfield Golden PM₁₀ measurement may signify impacts from local emission sources.

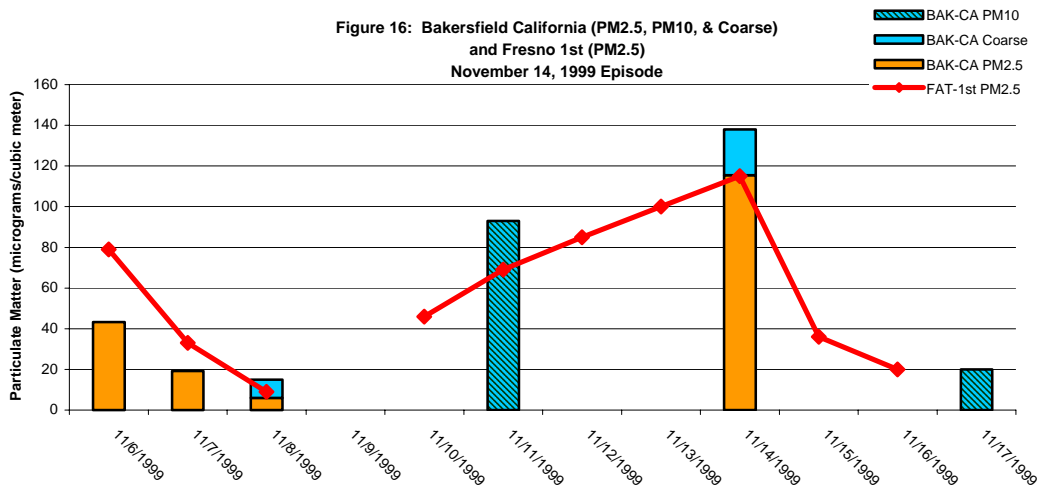
Other FRM Monitoring sites across the central and southern San Joaquin Valley (Visalia, Fresno, Hanford, Clovis, and Corcoran) measured 24-hour PM₁₀ above 100 µg/m³, but did not exceed the Federal 24-hour PM₁₀ standard. A weak upper level disturbance moved through the region late on the 14th and 15th, bringing better dispersion conditions and lowering Bakersfield's PM measurements to less the National Ambient Air Quality Standard.

7.0 INTEGRATED ANALYSIS OF ATMOSPHERIC CHEMISTRY AND METEOROLOGY DURING THE NOVEMBER 1999 EPISODE

The November 14, 1999 particulate episode was characterized by a short period (9 days) of strong stability and light wind flow, which resulted in poor atmospheric dispersion conditions across the San Joaquin Valley. Coarse and fine particulates accumulated during the period, leading to an exceedance of the 24 - hour standard at one monitoring site on November 14, 1999. Concentrations were dominated by the fine particulates ($PM_{2.5}$) of ammonia nitrate and sulfate and were most prevalent in the central and southern San Joaquin Valley. The highest PM_{10} measured was $183 \mu\text{g}/\text{m}^3$ (**Figure 15**) at Bakersfield-Golden; whereas, PM_{10} concentrations at other central and southern Valley locations were much lower between 130 to $140 \mu\text{g}/\text{m}^3$ (**Figure 16**). During the period, strong high pressure at the surface and aloft resulted in limited afternoon mixing and light offshore wind flow. Cool damp mornings and strong stability contributed to the formation of nitrates and sulfates during the episode. These meteorological conditions led to elevated particulate concentrations. Chemical composition and meteorological data around November 14, 1999, was evaluated and analyzed to identify the characteristics and uniqueness of the exceedance at Bakersfield-Golden.



Although PM_{10} sampling is not conducted daily, information from more frequent $PM_{2.5}$ sampling combined with an assessment of changes in the meteorological conditions suggest that the highest PM_{10} concentration was captured on the sampled day. With no chemical composition data available at the exceedance site, similarities in trends from other sites were analyzed in order to conclude which chemical components were responsible for the exceedance. It appears that the exceedance was driven by high concentrations of ammonium nitrate and sulfate comprising about 50 to 60 % of the PM_{10} mass. The other chemical components of the samples were composed of 10 to 15 % total carbon and 10 to 15% geological of the PM_{10} mass. The size fraction data across the Valley indicated that most of the PM_{10} was in the $PM_{2.5}$ fraction, with an



average PM_{2.5}/PM₁₀ mass ratio of greater than 0.8. This was further supported by the high PM_{2.5} concentrations that reached 134 µg/m³ at the exceedance site, accounting for 73 percent of the PM₁₀ mass, (**Figure 15**). All monitoring sites exceeded the federal PM_{2.5} standard on the exceedance day.

The concentration of coarse material may have been higher at the exceedance site relative to other sites in the Valley, as indicated by the higher coarse fraction at Bakersfield Golden as compared to other sites in the Valley. The coarse mass at Bakersfield-Golden, at 49 µg/m³, was 26 µg/m³ higher compared to nearby Bakersfield-California, indicating that a larger concentration of urban geological material at Bakersfield-Golden may be responsible for the large disparity in the PM₁₀ concentrations. Agriculture burning probably did not contribute to PM on the exceedance day, because November 13 and 14, 1999 were declared No Burn Day's District-wide. However, burn variances and noncompliant agricultural burns may have contributed to a small portion of the samples. Although minimum temperatures were mild compared to later in the middle of winter, overnight temperatures in the mid to upper 40's suggest that residential wood burning may have been a potential source of PM₁₀. PM₁₀ and PM_{2.5} concentrations showed that meteorological conditions led to the short pollution buildup. During the buildup time leading to the exceedance on November 14, 1999, carbon concentrations decreased or remained stable, whereas concentrations of geologic, ammonia nitrate, and sulfate increased.

Meteorologically, dispersion worsened and particulate formation conditions strengthened from November 8th to the 14th. After the passage of a cold front on November 8th, which brought 0.31 inches of rainfall to Bakersfield, moisture was available for atmospheric chemistry reactions. Humidity measurements of 85-100% in the morning across the Valley Floor showed a very moist atmosphere, with light to dense fog and haze being reported. The cool damp mornings and strong stability favored the formation of nitrates and sulfates. The eastern Pacific high built over the San Joaquin Valley on November 8th and dominated the region's weather through the

14th. The high strengthened and intensified a few days prior to the 14th, further tightening the lid and trapping pollutants within the San Joaquin Valley boundary layer.

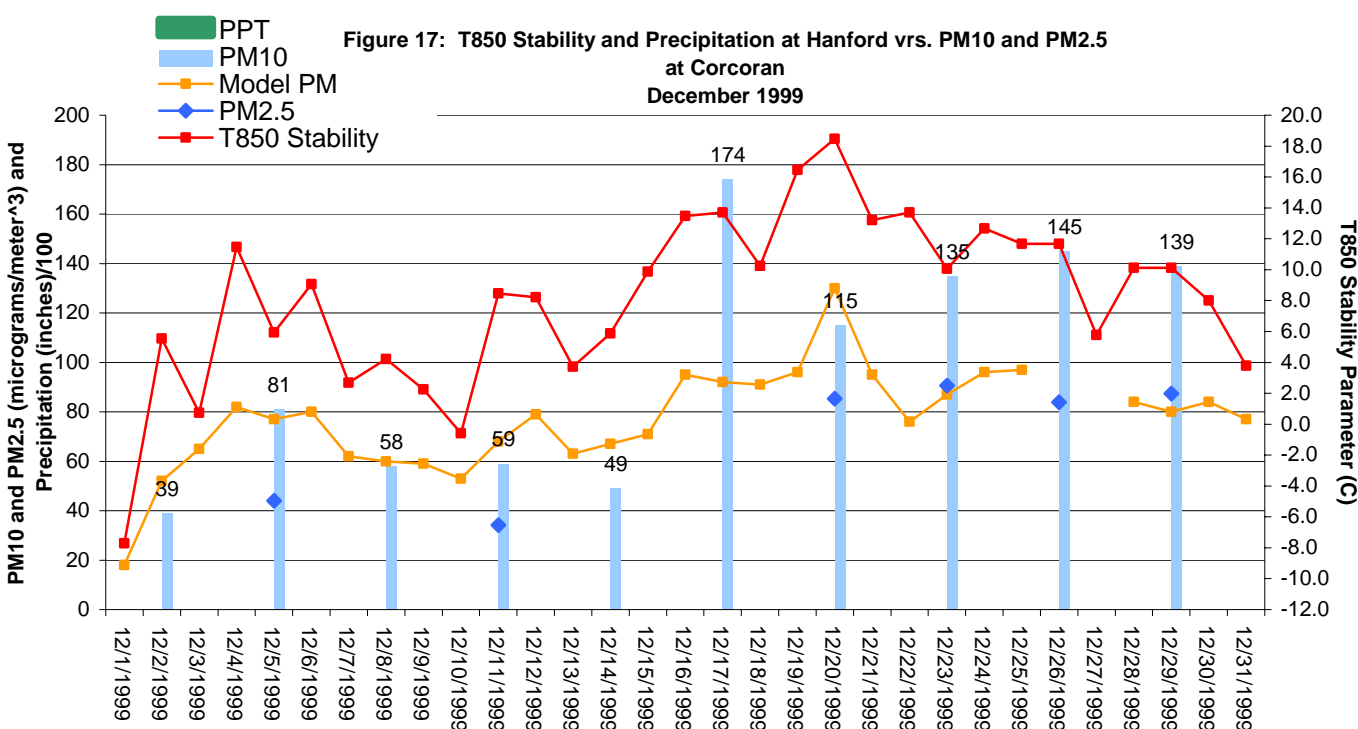
With a strong lid in place and maximum high temperatures in the mid to upper 70's, the afternoon hours were marked by limited mixing, resulting in increasing particulate conditions. Mixing heights at Fresno remained below 500 feet under a strong inversion for 16 hours on November 14, 1999 breaking out by 11:00 AM and reforming shortly after 5:00 P.M. During the afternoon hours, there were higher mixing depths (maximum mixing depth of 2,000 feet), but the bulk of the day had limited mixing. Maximum and minimum temperatures for the November 1999 episode were above normal, further illustrating the intensity of the high pressure system that was controlling the region's weather. Satellite imagery depicted scattered upper level moisture (high cloudiness) over the region and light fog being reported at the Valley surface on the November 14, resulting in slightly lower levels of solar radiation intensity. Along with lower solar radiation intensities due to the low sun angle and decreasing daylight hours, the atmospheric chemistry reactions may have favored the secondary particulate forming regime.

Chemical composition and meteorological data showed limited mixing depths and light and disorganized wind flow resulted in minimal transport and dispersion of pollutants. Both primary and secondary pollutants from local emissions around Bakersfield-Golden accumulated, resulting in the exceedance of the 24-hour PM₁₀ standard on November 14, 1999.

8.0 DECEMBER 17 AND 23, 1999 EPISODE SYNOPTIC METEOROLOGICAL DISCUSSION

December 10 – December 31, 1999

The period from December 10, 1999 through December 31st, 1999 was marked by 21 days of strong stability and poor atmospheric dispersion conditions. Strong high pressure over the Intermountain Region dominated the period, leading to light and disorganized wind flow and limited dispersion. The period began with the passage of a weak cold front and trough on the 9th. Between the 10th and the 17th, increasing stability and poor dispersion conditions resulted in a PM₁₀ exceedance at Corcoran on the 17th, **Figure 17**.



At Corcoran, a 24-hour PM₁₀ (Particulate Matter) concentration of 174 µg/m³ was measured. **Table 9** outlines federal reference method (FRM) Daily Average Particulate Matter measurements for sites across the San Joaquin Valley (SJV). In order to understand the variability of these measurements, an in depth examination of the synoptic pattern and surface winds and observations, and aircraft soundings leading to the episode were analyzed.

TABLE 9: Federal Reference Method (FRM) Daily Average Particulate Matter measurements for sites across the SJV for December 17, 1999.

	FRM			FRM			FRM	
Site Name	24-Avg.		Site Name	24-Avg.		Site Name	24-Avg.	
	10	2.5		10	2.5		10	2.5
Bakersfield-Gold		92	Modesto	99	93	Corcoran*	174	
Bakersfield-CA	111	90	Merced-M St.		75	Stockton**		78
Visalia		114	Clovis		18	Fresno-1 st		107

*-Patterson **- Hazleton

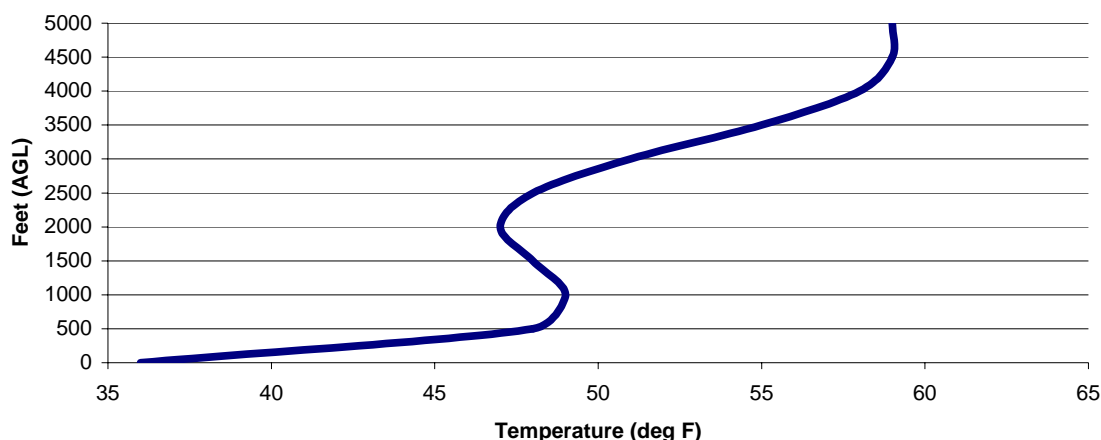
units in $\mu\text{g}/\text{m}^3$

The meteorological synoptic analysis showed a period of moderately strong atmospheric stability from December 10th through the 17th. Ahead of a developing trough over the eastern Pacific, a strong mid and upper level ridge developed over the region on the 17th. This ridge strengthened the inversion over the San Joaquin Valley trapping particulates within the Valley boundary layer. The morning surface charts of the 17th depicted a strong surface high over the Great Basin and Intermountain Region. The 12Z (4 a.m.) surface pressure gradient was +1.8 millibars from San Francisco (SFO) to Las Vegas (LAS), with isobars (constant surface pressure) orientated west to east. The alignment of the isobars and the +1.8 millibars pressure gradient, represents light and disorganized wind flow across the San Joaquin Valley. Visibilities throughout the day across the San Joaquin Valley were reporting haze.

The morning temperature aircraft sounding over Fresno on the 17th showed multiple inversions, with a strong inversion (stable layer) of 13 degrees Fahrenheit from the surface up to 1,000 feet, with a secondary strong inversion of 11 degrees Fahrenheit from 2,500 to 5,000 feet as is evident in **Figure 18**. The morning temperature sounding over Bakersfield also showed multiple inversions, with a strong inversion of 15 degrees Fahrenheit from the surface up to 3,000 feet, with a secondary strong inversion of 11 degrees Fahrenheit from 4,500 feet to 5,000 feet. The temperature sounding on the 17th, is conducive of elevated PM levels due to low mixing depths and multiple inversions, which keep pollutants trapped near the surface. During the early morning surface observations across the San Joaquin Valley were cold. The minimum temperatures recorded at Fresno and Bakersfield were 33 degrees Fahrenheit. The maximum high temperatures recorded at Fresno and Bakersfield were 59 degrees Fahrenheit. Fresno hourly temperature data shows very limited mixing conditions below 500 feet for over 18 hours of the day, increasing with minor afternoon heating to a

maximum mixing depth of 2,000 feet on the 17th.

Figure 18: Atmospheric Temperature Profile at Fresno on December 17, 1999



Upper level charts indicated a strong high just west of Santa Barbara, with a ridge building northeastward into the Great Basin. A weak trough over the extreme Pacific Northwest extended southward to near Eureka. Weak pressure gradients across the San Joaquin Valley remained rather flat through the day, leading to light and disorganized wind flow across the San Joaquin Valley.

Table 10 shows the 24 hour daily average wind speeds at SJVAPCD monitoring, ASOS, and CIMIS sites for December 17, 1999.

SJVAPCD Monitoring Sites		ASOS		CIMIS			
	WS		WS		WS		WS
	MPH		MPH		MPH		MPH
Clovis	2.2	Fresno	1.7	Shafter/USDA	2.1	Famoso	2.4
Fresno SSP	1.4	Bakersfield	3.4	Firebaugh/Telles	2.2	Westlands	2.6
Corcoran	2.8	Hanford	1.0	Stratford	2.4	Panoche	2.6
Edison	3.3			Kettleman	2.6	Arvin-Edison	2.3
Parlier	3.2			Visalia/Americas	2.1	Lindcove	1.8
Arvin	2.2			Parlier	2.2	Kesterson	2.4
Visalia	1.6			Blackwells Corner	2.0	Lodi West	1.8
				Los Banos	2.8	Modesto	2.9
				Manteca	2.4	Fresno State	2.2

Due to the strong stability lasting for over 7 days, PM₁₀ steadily increase region-wide until the sampling day on December 17th. With the mid and upper level stability aloft, surface based inversion, and light and disorganized wind flow, this weather pattern was conducive of an elevated region-wide PM₁₀ measurements. At Visalia and Fresno 1st, fine particulates were above 100 µg/m³, further suggesting a widespread PM event across the San Joaquin Valley.

After a weak upper level trough passage on the 18th, strong high pressure rebuilt into the region from the eastern Pacific, with increasing stability and poor dispersion conditions through the next exceedance date on December 23rd at Fresno-Drummond Street and Hanford-Irwin Street. At Fresno-Drummond, a 24-hour PM₁₀ concentration of 168 µg/m³ and at Hanford a 24-hour PM₁₀ concentration of 156 µg/m³ was measured.

Table 11 Federal Reference Method (FRM) Daily Average Particulate Matter and **Table 12** California Regional Particulate Air Quality Study (CRPAQS) Measurements shows for sites across the San Joaquin Valley (SJV) for December 23. In order to understand the variability of these measurements, an in depth examination of the synoptic pattern and surface winds and observations, and aircraft soundings leading to the episode were analyzed.

TABLE 11: Federal Reference Method (FRM) Daily Average Particulate Matter Measurements for sites across the SJV for December 23, 1999.

FRM			FRM			FRM		
24-Avg.			24-Avg.			24-Avg.		
10 2.5			10 2.5			10 2.5		
Bakersfield-Gold		74	Modesto	119	95	Corcoran*	135	91
Bakersfield-CA	109	72	Merced-M St.		83	Stockton**		79
Visalia		85	Clovis		22	Fresno-1st		119

* -Patterson #-Wagner, ** - Hazleton

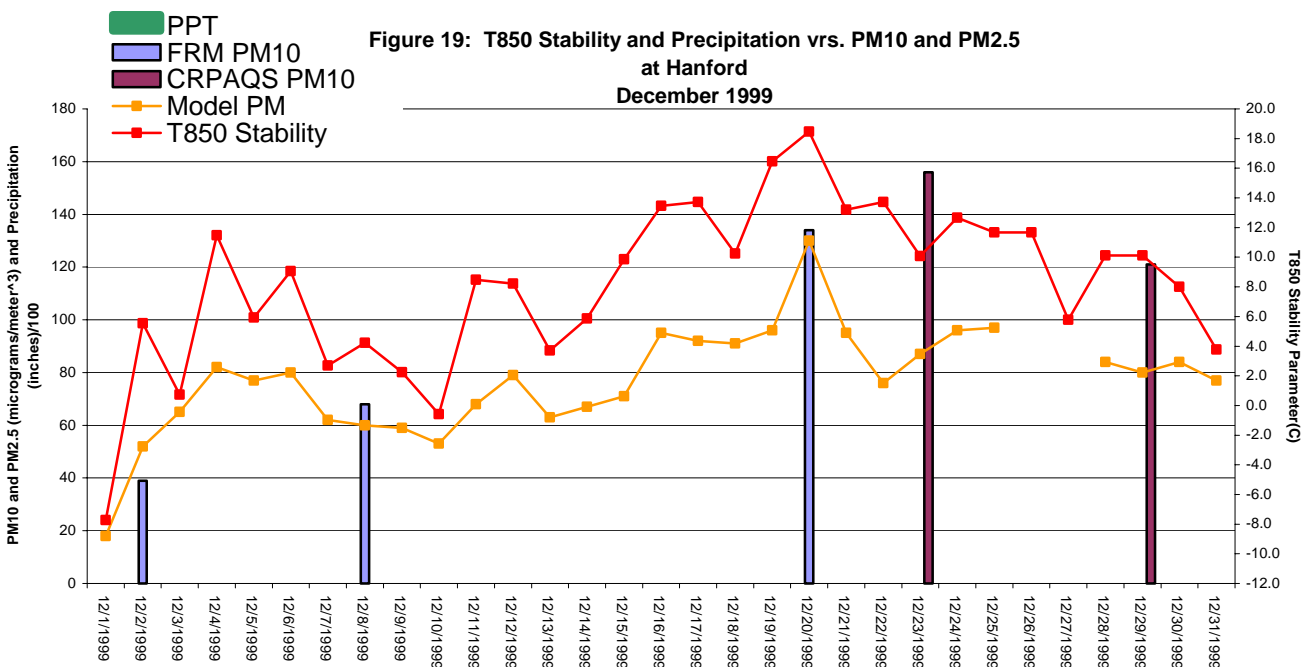
TABLE 12: California Regional Particulate Air Quality Study (CRPAQS) Daily Average Particulate Matter Measurements for Fresno-Drummond and Hanford-Irwin for December 23, 1999.

CRPAQS	
24-Avg.	
10	
Fresno-Drummond	168
Hanford-Irwin	156

units in µg/m³ for Table 11 and 12

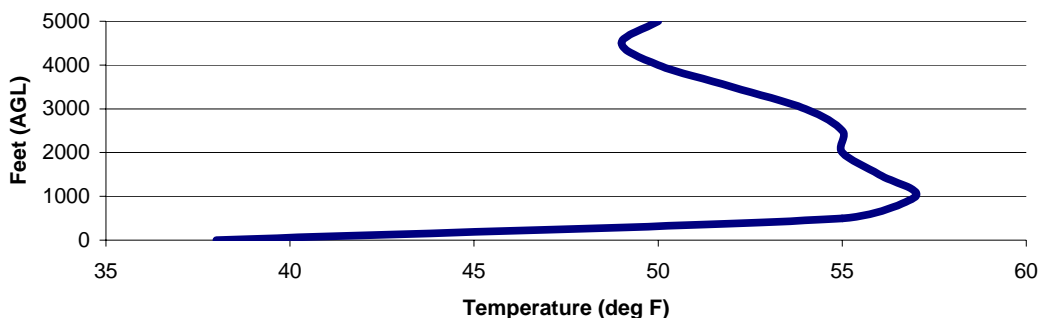
The meteorological synoptic analysis showed after a period of strong atmospheric stability from December 18th through the 23rd, increasing stability and poor dispersion conditions lead to two exceedances measured using CRPAQS monitors at Fresno-Drummond and Hanford, **Figure 19**. The morning surface charts on the 23rd depicted a surface ridge extending southwestward across the central San Joaquin Valley from strong highs anchored over the Intermountain Region. The morning surface pressure gradient was -1.6 millibars from San Francisco to Las Vegas (SFO-LAS), with isobars (constant surface pressure) orientated southeast to northwest. With the alignment of the isobars and -1.6 millibars pressure gradient, this represents light southeasterly wind

flow across the San Joaquin Valley. Visibilities across the San Joaquin Valley throughout the day reported hazy conditions.



The morning temperature aircraft sounding over Fresno depicted a strong inversion (stable layer) of 19 degrees Fahrenheit from the surface up to 1,000 feet as is evident in **Figure 20**. Bakersfield showed a strong inversion of 12 degrees Fahrenheit from the surface up to 1,000 feet turning isothermal up to 3,000 feet. The temperature soundings on the 23rd are indicative of elevated PM levels due to low mixing depths and strong inversions, which trap pollutants near the surface. During the early morning surface observations across the San Joaquin Valley were cold. The minimum temperatures recorded at Fresno and Bakersfield were 34 and 36 degrees respectively. The maximum high temperatures recorded at Fresno and Bakersfield were 62 and 64 degrees Fahrenheit respectively. Fresno hourly temperature data shows very limited mixing conditions below 500 feet for over 16 hours of the day, increasing with minor afternoon heating to a maximum mixing depth of 2,000 feet on the 23rd

Figure 20: Atmospheric Temperature Profile at Fresno on December 23, 1999



Upper level charts indicated a strong high 600 NM west of Santa Barbara, with a ridge building northward along the West Coast into the eastern Gulf of Alaska. Pressure gradients remained weak throughout the day leading to poor dispersion conditions across the San Joaquin Valley.

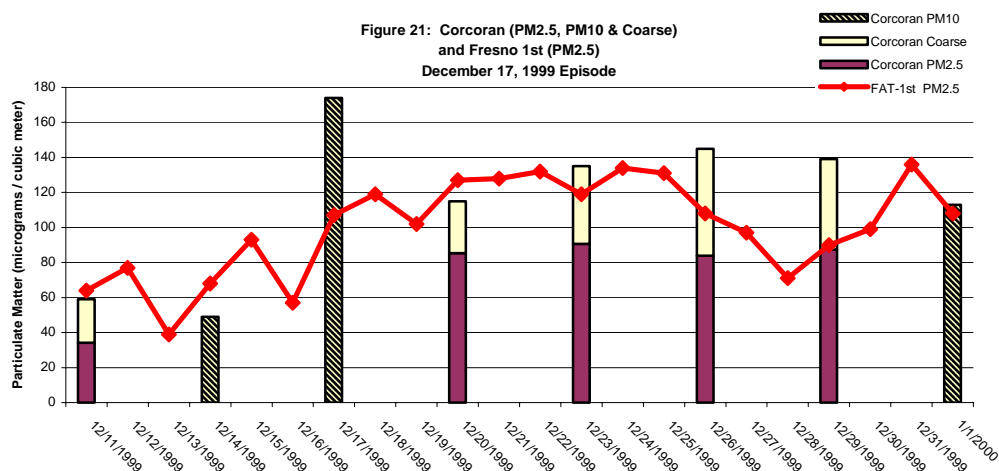
Table 13 shows the 24 hour daily average wind speeds at SJVAPCD monitoring, ASOS, and CIMIS sites for December 23, 1999.

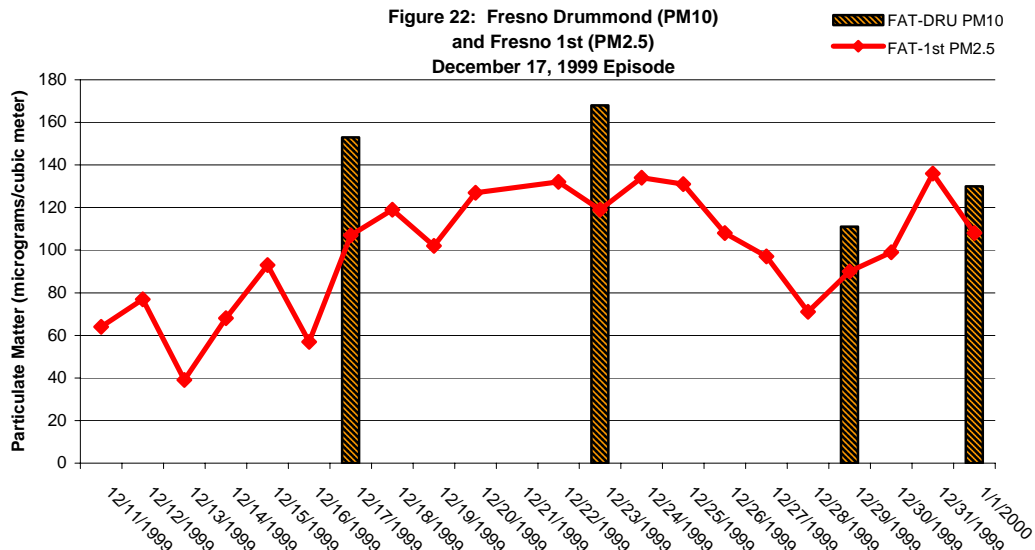
SJVAPCD Monitoring Site		ASOS		CIMIS			
	WS		WS		WS		WS
	MPH		MPH		MPH		MPH
Clovis	2.5	Fresno	1.5	Shafter/USDA	2.5	Famoso	2.5
Fresno SSP	2.1	Bakersfield	3.1	Firebaugh/Telles	2.5	Westlands	3.0
Corcoran	3.3	Hanford	1.6	Stratford	3.3	Panoche	2.7
Edison	3.7			Kettleman	3.3	Arvin-Edison	2.6
Parlier	3.9			Visalia/Americas	2.5	Lindcove	1.8
Arvin	2.4			Parlier	2.7	Kesterson	2.1
Visalia	1.7			Blackwells Corner	2.1	Lodi West	1.7
				Los Banos	2.8	Modesto	2.4
				Manteca	2.4	Fresno State	2.3

The period of December 10, 1999 through December 31st, 1999, marked one of the longest periods of strong stability in recent history. This pattern was similar to the one experienced during the California Regional Particulate Air Quality Study. The main difference between the two episodes was the CRPAQS event began a week later and continued into the early part of January. During the exceedances of 1999, they were preceded by an exceptionally dry fall. After a weak frontal passage on the 10th, which brought a cold air mass to the Valley, this air remained trapped within the Valley boundary layer resulting in strong surface based inversions. Coupled with the synoptic and surface pattern, which was indicative of light and disorganized wind flow, PM became a region-wide problem until a weak trough scoured out the area on New Year's Eve. As is evident in the PM data, local emissions contributed to the exceedance of the National Ambient Air Quality Standards at Corcoran on the 17th and Fresno-Drummond, and Hanford on the 23rd. If monitoring were done on a daily basis, more exceedances would have been recorded during this time frame at other San Joaquin Valley locations.

9.0 INTEGRATED ANALYSIS OF ATMOSPHERIC CHEMISTRY AND METEOROLOGY DURING THE DECEMBER 1999 EPISODE

The December 1999 particulate episode was characterized by a prolonged period (three weeks) of strong stability and light wind flow, which resulted in poor atmospheric dispersion conditions across the San Joaquin Valley. Coarse and fine particulates accumulated during the period, leading to two separate exceedance days on December 17 and 23, 1999. Concentrations were dominated by fine particulates (PM_{2.5}) of ammonia nitrate and sulfate and were most prevalent in the central and southern San Joaquin Valley. The highest PM₁₀ measured on December 17, 1999 was 174 µg/m³ (**Figure 21**) at Corcoran, a federal reference monitoring (FRM) site. PM₁₀ at other central and southern Valley locations were elevated but not over the standard. For example, Fresno-Drummond recorded 153 µg/m³ on December 17, 1999 (**Figure 22**). Stagnation conditions continued through December 23, 1999, when two MiniVol Samplers, which were part of the California Regional Particulate Air Quality Study (CRPAQS) registered the second and third highest concentrations at Fresno-Drummond at 168 µg/m³ and Hanford-South Irwin, at 156 µg/m³. The CRPAQS exceedances are not considered for compliance with the standards, but are used in the discussion to provide context to the episode. During the period, strong high pressure at the surface and aloft resulted in limited afternoon mixing and light offshore wind flow. Cool damp mornings and strong stability contributed to the formation of nitrates and sulfates during the episode. Chemical composition and meteorological data around December 17 and 23, 1999 were evaluated and analyzed to identify the characteristics and uniqueness of the exceedances at Corcoran, Fresno-Drummond, and Hanford-South Irwin.





Although PM₁₀ sampling is not conducted daily, information from more frequent PM_{2.5} sampling combined with an assessment of changes in the meteorological conditions suggest that the highest PM₁₀ concentration was not captured on the sample day. Daily PM_{2.5} sampling and meteorological conditions suggested that the highest PM₁₀ concentrations may have occurred on December 18th, when Fresno 1st measured a peak PM_{2.5} concentration of 119 µg/m³. With the lack of chemical composition data for the exceedance site, similarities in trends from other sites such as Fresno-Drummond were drawn in order to determine the chemical components responsible for the December 17th exceedance. The analysis shows that the exceedance was driven by high concentrations of ammonium nitrate and sulfate that comprised of 55 to 75 % of the PM₁₀ mass. The other major chemical components of the samples were 25 to 30 % total carbon and 20 to 25 % geological of the PM₁₀ mass. The size fraction data across the Valley indicated that most of the PM₁₀ was in the PM_{2.5} fraction, with an average PM_{2.5}/PM₁₀ mass ratio greater than 0.8. This was further supported by the high PM_{2.5} concentrations that reached 107 µg/m³ at nearby Fresno-First, (**Figure 22**).

The concentration of total carbon (27% of PM₁₀ mass) and coarse material (20% of PM₁₀ mass) at Fresno Drummond show the main constituents of the particulate samples on December 17, 1999 may have come from local sources (residential wood burning and urban/agricultural geologic). Light afternoon mixing and wind flow may have allowed some transported contribution from agricultural burning in Merced, Stanislaus, and San Joaquin Counties on December 17th. However a no burn day across the rest of the Valley, indicates that stagnant conditions favored a larger influence from local emissions. Burn variances and noncompliant agricultural burns may have contributed to a small portion of the samples. Overnight minimum temperatures in the low 30's suggest that residential wood burning may have been a significant source of PM₁₀. Analysis of PM₁₀ and PM_{2.5} concentrations showed that meteorological conditions led to the pollution buildup. Ammonium nitrate and sulfates, carbon, and geological material increased prior to the exceedance on December 17, 1999 and then later accumulated further leading to two other monitoring sites exceedances on December 23.

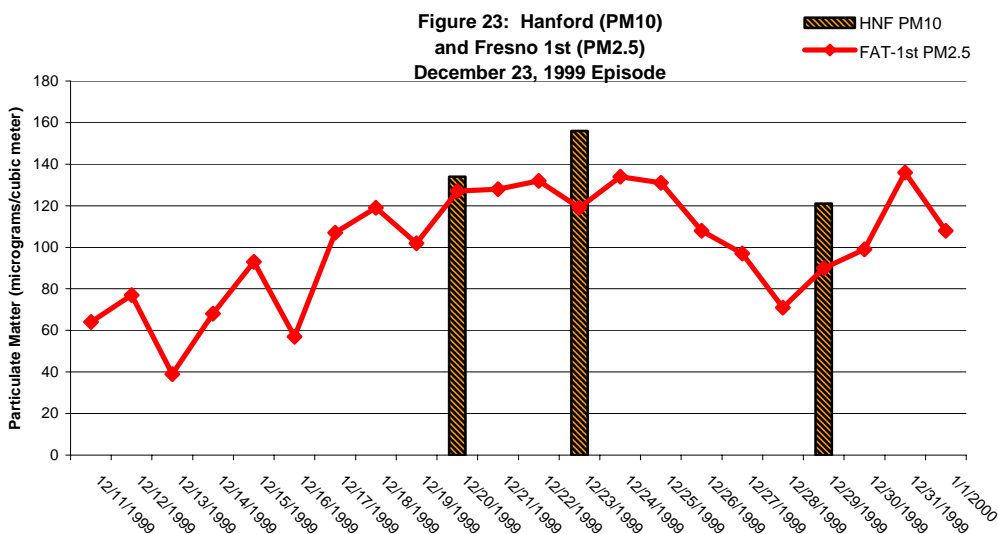
Meteorologically, dispersion worsened and particulate formation conditions strengthened from December 10th to the 17th. After the passage of a weak cold front on December 9th, which brought trace amounts of precipitation to the region, moisture was available for atmospheric chemistry reactions. Humidity measurements of 85 – 100 % in the morning across the Valley Floor showed a moist atmosphere, with light to dense fog and haze being reported. These cool damp mornings and strong stability favored the formation of nitrates and sulfates. Synoptically, the eastern Pacific high built over the San Joaquin Valley on December 10th and dominated the region's weather through the 31st. The high strengthened and intensified a few days prior to the 17th, further tightening the lid and trapping pollutants within the San Joaquin Valley boundary layer.

With a strong lid in place aloft and maximum high temperatures in the upper 50's, the afternoon hours were marked by limited mixing, resulting in increasing particulate potential. Mixing heights at Fresno remained below 500 feet under a strong inversion for 18 hours on December 17th, breaking out after 12:00 P.M and reforming shortly before 5:00 P.M. During the afternoon hours, there were higher mixing depths (maximum mixing depth of 2,000 feet), but the bulk of the day had limited mixing. Maximum and minimum temperatures for this episode were slightly above normal, further illustrating the intensity of the high pressure system that was controlling the region's weather. Light fog was reported at the Valley surface during the early morning hours of December 17th, resulting in slightly lower solar radiation intensities. Along with lower solar radiation intensities due to the early morning fog, lowering sun angle, and decreasing daylight hours, the atmospheric chemistry reactions may have favored the secondary particulate forming regime.

Chemical composition and meteorological data showed limited mixing depths and light and disorganized wind flow resulted in minimal transport and dispersion of pollutants. Both primary and secondary pollutants from local emissions around Corcoran accumulated resulting in the exceedance of the 24- hour PM₁₀ standard on December 17, 1999.

Between December 17th through the 23rd, meteorological conditions remained stable leading to elevated particulate conditions continuing across the San Joaquin Valley. Without a significant weather disturbance moving through the area to scour out the particulates, PM₁₀ concentrations became a region-wide problem and came very close to the standard at three monitoring sites (Fresno-1st at 154 µg/m³, Visalia at 152 µg/m³, and Clovis at 151 µg/m³) on December 20, 1999. PM₁₀ concentrations from Fresno-Drummond and Hanford climbed between December 17th through the 23rd, while PM₁₀ concentrations at Corcoran lowered during this time frame. Due to the light winds and limited mixing, local emission activity around Corcoran may have lowered leading to decreasing PM₁₀ levels. Analysis of total carbon and ammonium nitrates and sulfates indicates that Fresno-Drummond and Hanford registered higher levels compared to Corcoran, indicating potentially that local emissions sources may have impacted these sites. A few days later, two MiniVol Samplers, which were collected as part of the California Regional Particulate Air Quality Study (CRPAQS), measured the second and

third highest concentrations at Fresno-Drummond at $168 \mu\text{g}/\text{m}^3$ (**Figure 22**) and Hanford-South Irwin, at $156 \mu\text{g}/\text{m}^3$ (**Figure 23**). The CRPAQS exceedances are not considered for compliance with the standards, but are used in the discussion to provide context to the episode.



Although PM₁₀ sampling is not conducted daily, information from more frequent PM_{2.5} sampling combined with an assessment of changes in the meteorological conditions suggest that the highest PM₁₀ concentration was not captured on the sampled day. Daily PM_{2.5} sampling and meteorological conditions suggested that the highest PM₁₀ concentrations may have occurred on December 24th and 25th, when Fresno 1st measured peak PM_{2.5} concentrations of 134 and 131 $\mu\text{g}/\text{m}^3$, respectively. The exceedances at Fresno-Drummond and Hanford-Irwin were driven by high concentrations of ammonia nitrate and sulfate and/or total carbon, which accumulated between December 17th and the 23rd. The size fraction data across the Valley indicated that most of the PM₁₀ was in the PM_{2.5} fraction, with an average PM_{2.5}/PM₁₀ mass ratio greater than 0.7. This was further supported by the high PM_{2.5} concentrations that reached 119 $\mu\text{g}/\text{m}^3$ at nearby Fresno-First, (**Figure 22 & 23**).

The concentration at Fresno-Drummond of ammonium nitrate and sulfate ($74 \mu\text{g}/\text{m}^3$), total carbon ($44 \mu\text{g}/\text{m}^3$), and geological ($44 \mu\text{g}/\text{m}^3$), had the highest PM₁₀ mass in the Valley. The concentration at Hanford of ammonium nitrate and sulfate ($80 \mu\text{g}/\text{m}^3$), total carbon ($35 \mu\text{g}/\text{m}^3$), and geological ($44 \mu\text{g}/\text{m}^3$), had the second highest PM₁₀ mass in the Valley. The main constituents of the particulate samples on December 23, 1999 may have come from local sources (residential wood burning and urban/agricultural geologic). Agricultural burning may not have contributed as a potential source of PM on the exceedance day, because since December 18, 1999 were declared a No Burn Day's District-wide. However, burn variances and noncompliant agricultural burns may have contributed to a small portion of the samples. Overnight minimum temperatures in the low to mid 30's suggest that residential wood burning was likely to be a significant

source of PM₁₀. It appears that potentially residential burning may have been a source of carbon. PM₁₀ and PM_{2.5} concentrations showed that meteorological conditions led to the pollution buildup. During the buildup time leading to the two separate exceedances on December 23, 1999, where ammonium nitrate and sulfates, carbon, and geological material increased.

Meteorologically, dispersion conditions began to slightly improve a few days prior to the December 23rd exceedances. The lack of precipitation since December 9th may have contributed to the increasing geological component. Humidity measurements of 85 – 100 % in the morning across the Valley Floor showed a moist atmosphere, with light to dense fog and haze being reported. The cool damp mornings and strong stability favored the formation of nitrates and sulfates. The eastern Pacific high remained strong through the 20th and gradually weakened through the 31st, keeping a tight lid over the San Joaquin Valley trapping the pollutants within the Valley boundary layer.

With a strong lid in place aloft and maximum high temperatures in the low 60's, the afternoon hours were marked by limited mixing, resulting in increasing particulate conditions. Mixing heights at Fresno remained below 500 feet under a strong inversion for 16 hours on the December 23rd, breaking out shortly after 12:00 P.M and reforming before 5:00 P.M. During the afternoon hours, there were higher mixing depths (maximum mixing depth of 2,000 feet), but the bulk of the day had limited mixing. Maximum temperatures for this episode were above normal, further illustrating the intensity of the high pressure system that was controlling the region's weather. Light fog reported at the Valley surface during the early morning hours, resulted in slightly lower solar radiation intensities. Along with lower solar radiation intensities due to the low sun angle and decreasing daylight hours, the atmospheric chemistry reactions may have favored the secondary particulate forming regime.

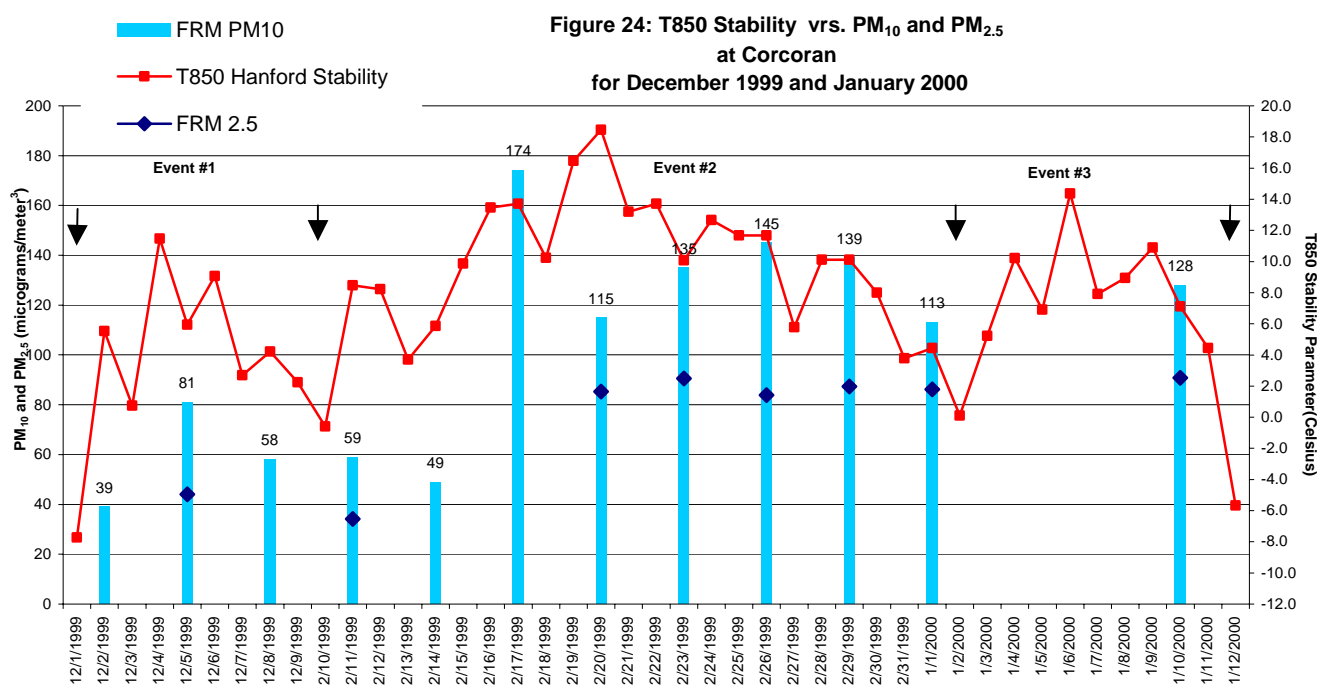
In summary, chemical composition and meteorological data showed limited mixing depths and light and disorganized wind flow resulted in minimal transport and dispersion of pollutants. Both primary and secondary pollutants from local emissions around Fresno-Drummond and Hanford-Irwin accumulated resulting in the exceedance of the 24-hour PM₁₀ standard on December 23, 1999.

10.0 DECEMBER 1999 AND JANUARY 2000 PM_{2.5} & PM₁₀ METEOROLOGICAL DISCUSSION

During December 1999 and January 2000 episode, strong high pressure at the surface and aloft resulted in limited morning and afternoon mixing and light offshore flow. Cool damp mornings and strong stability contributed to the formation of nitrates and sulfates during the episode. The December 1999 and January 2000 episode can be divided into three distinct events (**Figure 24**). These events, characterized by limited atmospheric dispersion, were separated by trough passages.

Each event was marked by limited mixing heights with strong inversions of approximately 500 feet for 18 or more hours of the day. Maximum mixing depths on the highest PM_{2.5} concentration days ranged between 1,000 to 2,500 feet. Moisture availability from recent rainfall and minimal solar insolation, led to prime nitrate and sulfate forming conditions. Typically, light fog, with humidity measurements between 85 – 100% were needed in order to maximize particulate forming potential. The higher the humidity, the heavier and wetter the fog, results in the removal of particulates by wet deposition.

Within these three distinct measurement periods, a violation of the Federal 24 hour PM_{2.5} National Ambient Air Quality Standard (NAAQS) of 65 micrograms / meter³ were recorded during the 1st and 3rd events at some locations across the San Joaquin Valley (**Figure 25**). The following analysis will investigate the meteorological and dispersion conditions surrounding each event.



*No precipitation occurred in Hanford from December 1, 1999 through January 12, 2000.

Event #1: December 1 through December 8, 1999

Atmospheric dispersion worsened and particulate formation conditions became more favorable from December 1st to December 6th in the San Joaquin Valley. As is evident in **Figure 25**, event #1 lasted about 9 days and was marked by one main PM_{2.5} peak, which exceeded the NAAQS. After the passage of a cold front on December 1, 1999, which brought trace amounts of precipitation across the San Joaquin Valley, moisture became available for atmospheric chemistry reactions. Humidity measurements of 85 – 100 % in the morning across the Valley Floor showed a moist air mass, with light fog and haze being reported on the 6th. These cool damp mornings and strong stability favored the formation of nitrates and sulfates. Since concentrations rose through the episode, it does not appear that the water content of the atmosphere was high enough to create deposition of particles that exceeded formation.

Synoptically, during the first part of event #1, the eastern Pacific ridge built over northern California on December 5th then expanded southward on the 6th, bringing increasing stability and poor dispersion conditions through the 7th. With a strong lid in place aloft and maximum high temperatures in the upper 50's on the 6th, the afternoon hours were marked by limited mixing, resulting in increasing particulate potential. Mixing heights at Fresno remained below 500 feet under a strong inversion during a majority of the day (20 or more hours) on the 6th. During the afternoon hours, there were moderate mixing depths of 1,500 feet but the bulk of the day had limited mixing. Maximum and minimum temperatures were near to slightly below normal, indicating a potential for increasing residential wood burning emission activity, and nitrate forming reactions.

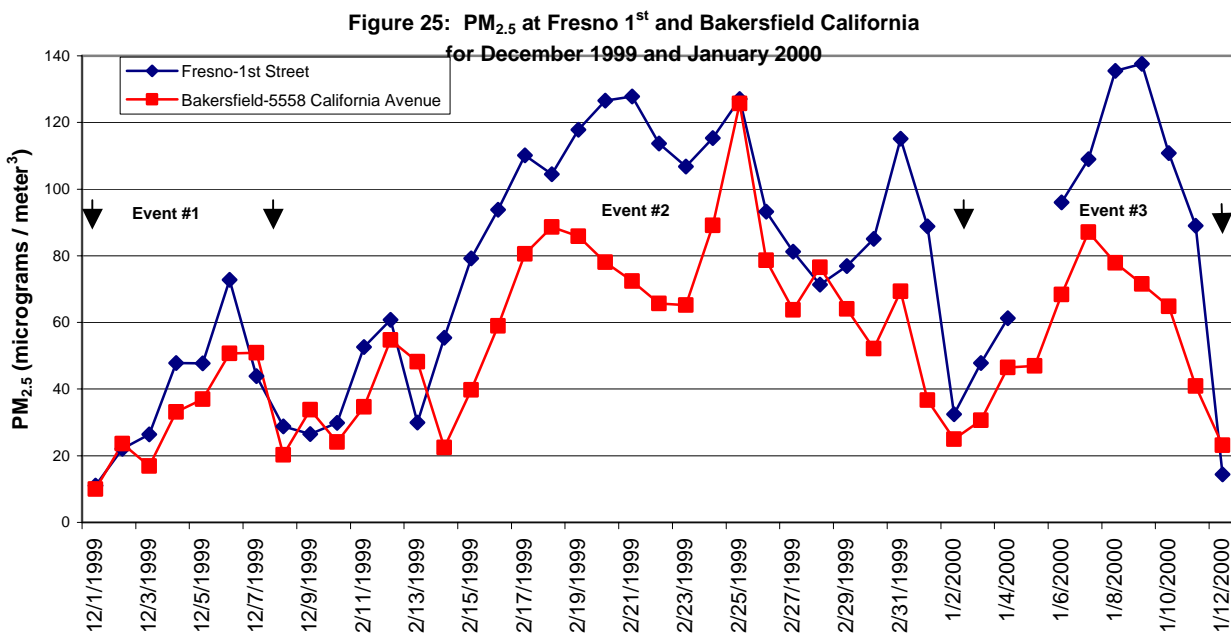
Meteorological data during event #1 showed limited mixing depths and light and disorganized wind flow resulted in minimal transport and dispersion of pollutants. Both primary and secondary pollutants from local emissions across the San Joaquin Valley accumulated resulting in the exceedance of the 24 hour PM_{2.5} NAAQS at Fresno-1st on December 6th. No other sites registered an exceedance on or around December 6th, thus indicating that local emissions drove the measurement above the NAAQS.

A cold front moved into northern California on the 7th and 8th, bringing an end to event #1 that lasted from December 1st through the 8th. The disturbance brought moderate dispersal conditions across the Valley, allowing pollutants to lower into the 20 to 30 micrograms per cubic meter range, but was not significant enough to drop PM_{2.5} levels to background.

Event #2: December 9 through December 31, 1999

The period from December 9, 1999 through December 31st, 1999 was marked by 22 days of strong stability and poor atmospheric dispersion conditions. Strong high pressure over the Intermountain Region dominated the period, leading to light and disorganized wind flow and limited dispersion. The period began with the passage of a

weak cold front and trough on the 9th. Between the 10th and the 17th, increasing stability and poor dispersion conditions resulted in a PM₁₀ exceedance at Corcoran on the 17th.



At Corcoran, a 24-hour PM₁₀ (Particulate Matter) concentration of 174 µg/m³ was measured. **Table 14** outlines federal reference method (FRM) Daily Average Particulate Matter measurements for sites across the San Joaquin Valley (SJV). In order to understand the variability of these measurements, an in depth examination of the synoptic pattern and surface winds and observations, and aircraft soundings leading to the episode were analyzed.

TABLE 14: Federal Reference Method (FRM) Daily Average Particulate Matter measurements for sites across the SJV for December 17, 1999.

Site Name	FRM		Site Name	FRM		Site Name	FRM	
	24-Avg.			24-Avg.			24-Avg.	
	10	2.5		10	2.5		10	2.5
Bakersfield-Gold		92	Modesto	99	93	Corcoran*	174	
Bakersfield-CA	111	90	Merced-M St.		75	Stockton**		78
Visalia		114	Clovis		18	Fresno-1 st		107

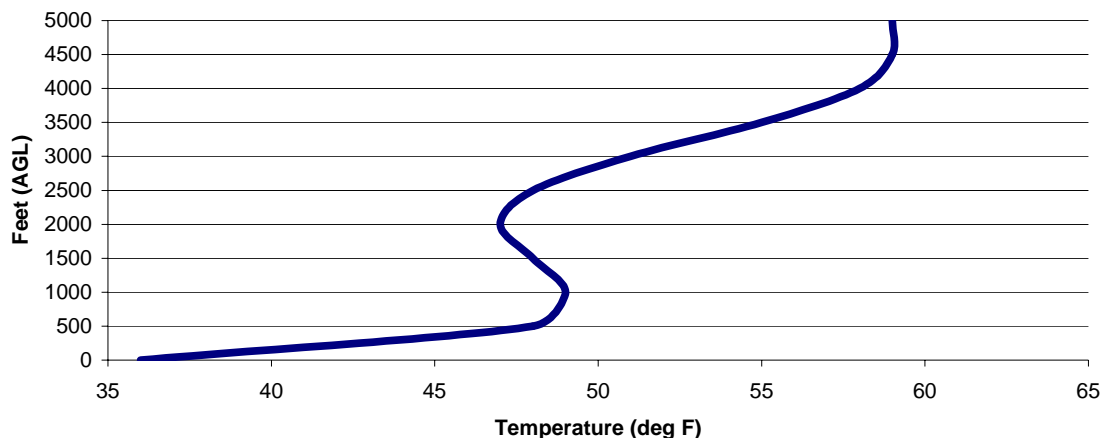
*-Patterson **- Hazleton
units in µg/m³

The meteorological synoptic analysis showed a period of moderately strong atmospheric stability from December 10th through the 17th. Ahead of a developing trough over the eastern Pacific, a strong mid and upper level ridge developed over the region on the 17th. This ridge strengthened the inversion over the San Joaquin Valley

trapping particulates within the Valley boundary layer. The morning surface charts of the 17th depicted a strong surface high over the Great Basin and Intermountain Region. The 12Z (4 a.m.) surface pressure gradient was –3.9 millibars from San Francisco (SFO) to Reno (RNO) (SFO-RNO), with isobars (constant surface pressure) orientated west to east. The alignment of the isobars and the –3.9 millibars pressure gradient, represented offshore wind flow across the San Joaquin Valley. Many sites across the San Joaquin Valley were reporting haze.

The morning temperature aircraft sounding over Fresno on the 17th showed multiple inversions, with a strong inversion (stable layer) of 13 degrees Fahrenheit from the surface up to 1,000 feet, with a secondary strong inversion of 11 degrees Fahrenheit from 2,500 to 5,000 feet as is evident in **Figure 26**. The morning temperature sounding over Bakersfield also showed multiple inversions, with a strong inversion of 15 degrees Fahrenheit from the surface up to 3,000 feet, with a secondary strong inversion of 11 degrees Fahrenheit from 4,500 feet to 5,000 feet. The temperature sounding on the 17th, is conducive of elevated PM levels due to low mixing depths and multiple inversions, which keep pollutants trapped near the surface. During the early morning surface observations across the San Joaquin Valley were cold. The minimum temperatures recorded at Fresno and Bakersfield were 33 and 43 degrees Fahrenheit respectively. The maximum high temperatures recorded at Fresno and Bakersfield were 59 and 57 degrees Fahrenheit respectively. Fresno hourly temperature data shows very limited mixing conditions below 500 feet for over 18 hours of the day, increasing with minor afternoon heating to a maximum mixing depth of 2,000 feet on the 17th.

Figure 26: Atmospheric Temperature Profile at Fresno on December 17, 1999



Upper level charts indicated a strong high just west of Santa Barbara, with a ridge building northeastward into the Great Basin. A weak trough over the extreme Pacific Northwest extended southward to near Eureka. Weak pressure gradients across the San Joaquin Valley remained rather flat through the day, leading to light and disorganized wind flow across the San Joaquin Valley.

Table 15 shows the 24 hour daily average wind speeds at SJVAPCD monitoring, ASOS, and CIMIS sites for December 17, 1999.

SJVAPCD Monitoring Sites		ASOS		CIMIS			
	WS		WS		WS		WS
	MPH		MPH		MPH		MPH
Clovis	2.2	Fresno	1.7	Shafter/USDA	2.1	Famoso	2.4
Fresno SSP	1.4	Bakersfield	3.4	Firebaugh/Telles	2.2	Westlands	2.6
Corcoran	2.8	Hanford	1.0	Stratford	2.4	Panoche	2.6
Edison	3.3			Kettleman	2.6	Arvin-Edison	2.3
Parlier	3.2			Visalia/Americas	2.1	Lindcove	1.8
Arvin	2.2			Parlier	2.2	Kesterson	2.4
Visalia	1.6			Blackwells Corner	2.0	Lodi West	1.8
				Los Banos	2.8	Modesto	2.9
				Manteca	2.4	Fresno State	2.2

Due to the strong stability lasting for over 7 days, PM₁₀ steadily increase region-wide until the sampling day on December 17th. With the mid and upper level stability aloft, surface based inversion, and light and disorganized wind flow, this weather pattern was conducive of an elevated region-wide PM₁₀ measurements. Light south – southeast to west – northwest transport wind flow of 4 to 6 miles per hour occurred during a few hours on the 17th. At Visalia and Fresno 1st, fine particulates were above 100 µg/m³, further suggesting a widespread PM event across the San Joaquin Valley.

After a weak upper level trough passage on the 18th, strong high pressure rebuilt into the region from the eastern Pacific, with increasing stability and poor dispersion conditions through the next exceedance date on December 23rd at Fresno-Drummond Street and Hanford-Irwin Street. At Fresno-Drummond, a 24-hour PM₁₀ concentration of 168 µg/m³ and at Hanford a 24-hour PM₁₀ concentration of 156 µg/m³ was measured.

Table 16 Federal Reference Method (FRM) Daily Average Particulate Matter and **Table 17** California Regional Particulate Air Quality Study (CRPAQS) Measurements shows for sites across the San Joaquin Valley (SJV) for December 23. In order to understand the variability of these measurements, an in depth examination of the synoptic pattern and surface winds and observations, and aircraft soundings leading to the episode was done.

TABLE 16: Federal Reference Method (FRM) Daily Average Particulate Matter Measurements for sites across the SJV for December 23, 1999.

	FRM			FRM			FRM	
Site Name	24-Avg.		Site Name	24-Avg.		Site Name	24-Avg.	
	10	2.5		10	2.5		10	2.5
Bakersfield-Gold		74	Modesto	119	95	Corcoran*	135	91
Bakersfield-CA	109	72	Merced-M St.		83	Stockton**		79
Visalia		85	Clovis		22	Fresno-1 st		119

* -Patterson # -Wagner, ** - Hazleton

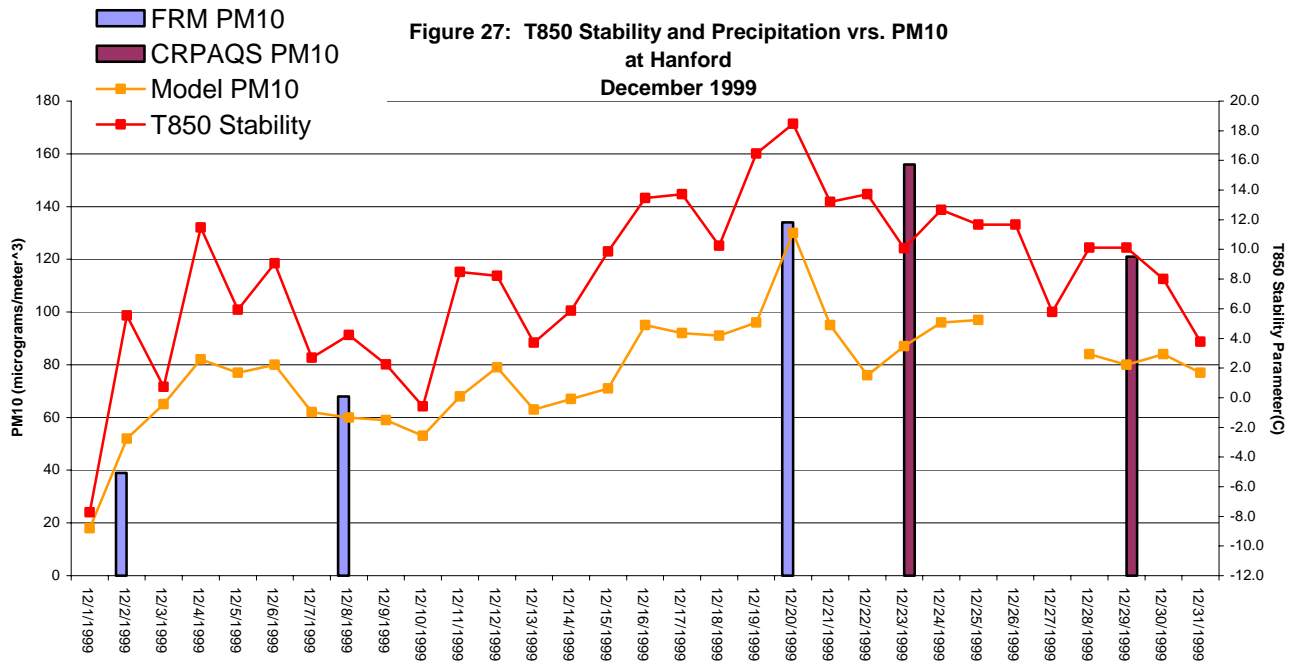
TABLE 17: California Regional Particulate Air Quality Study (CRPAQS) Daily Average Particulate Matter Measurements for Fresno-Drummond and Hanford-Irwin for December 23, 1999.

	CRPAQS
Site Name	24-Avg.
	10
Fresno-Drummond	168
Hanford-Irwin	156

units in $\mu\text{g}/\text{m}^3$ for Table 16 and 17

The meteorological synoptic analysis showed after a period of strong atmospheric stability from December 18th through the 23rd, increasing stability and poor dispersion conditions lead to two exceedances of the PM₁₀ NAAQS measured using CRPAQS monitors at Fresno-Drummond and Hanford, **Figure 27**. The morning surface charts on the 23rd depicted a surface ridge extending southwestward across the central San Joaquin Valley from strong highs anchored over the Intermountain Region. The morning surface pressure gradient was -7.6 millibars from San Francisco to Reno (SFO-RNO), with isobars (constant surface pressure) orientated southeast to northwest. With the alignment of the isobars and -7.6 millibars pressure gradient, this represented light to moderate offshore wind flow across the San Joaquin Valley. Light southeasterly transport wind flow of 5 to 8 miles per hour occurred for a few hours of the day. .

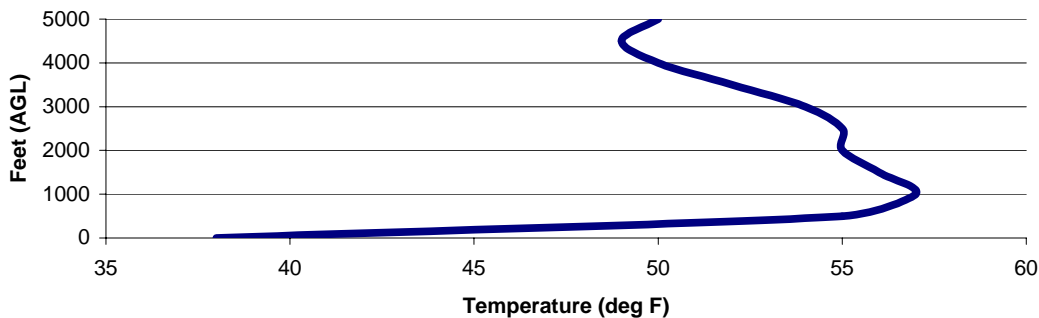
Visibility reports across the San Joaquin Valley indicated hazy conditions throughout the day.



*No precipitation occurred in Hanford from December 1, 1999 through December 31, 1999.

The morning temperature aircraft sounding over Fresno depicted a strong inversion (stable layer) of 19 degrees Fahrenheit from the surface up to 1,000 feet as is evident in **Figure 28**. Bakersfield showed a strong inversion of 12 degrees Fahrenheit from the surface up to 1,000 feet turning isothermal up to 3,000 feet. The temperature soundings on the 23rd are indicative of elevated PM levels due to low mixing depths and strong inversions, which trap pollutants near the surface. During the early morning surface observations across the San Joaquin Valley were cold. The minimum temperatures recorded at Fresno and Bakersfield were 34 and 36 degrees respectively. The maximum high temperatures recorded at Fresno and Bakersfield were 62 and 64 degrees Fahrenheit respectively. Fresno hourly temperature data shows very limited mixing conditions below 500 feet for over 16 hours of the day, increasing with minor afternoon heating to a maximum mixing depth of 2,000 feet on the 23rd

Figure 28: Atmospheric Temperature Profile at Fresno on December 23, 1999



Upper level charts indicated a strong high 600 NM west of Santa Barbara, with a ridge building northward along the West Coast into the eastern Gulf of Alaska. Pressure gradients remained weak throughout the day leading to poor dispersion conditions across the San Joaquin Valley.

Table 18 shows the 24 hour daily average wind speeds at SJVAPCD monitoring, ASOS, and CIMIS sites for December 23, 1999.

SJVAPCD Monitoring Site		ASOS		CIMIS			
	WS		WS		WS		WS
	MPH		MPH		MPH		MPH
Clovis	2.5	Fresno	1.5	Shafter/USDA	2.5	Famoso	2.5
Fresno SSP	2.1	Bakersfield	3.1	Firebaugh/Telles	2.5	Westlands	3.0
Corcoran	3.3	Hanford	1.6	Stratford	3.3	Panoche	2.7
Edison	3.7			Kettleman	3.3	Arvin-Edison	2.6
Parlier	3.9			Visalia/Americas	2.5	Lindcove	1.8
Arvin	2.4			Parlier	2.7	Kesterson	2.1
Visalia	1.7			Blackwells Corner	2.1	Lodi West	1.7
				Los Banos	2.8	Modesto	2.4
				Manteca	2.4	Fresno State	2.3

The period of December 9, 1999 through December 31st, 1999, marked one of the longest periods of strong stability in recent history. This pattern was similar to the one experienced during the California Regional Particulate Air Quality Study. The main difference between the two episodes was the CRPAQS event began a week later and continued into the early part of January. During the exceedances of 1999, they were preceded by an exceptionally dry fall. After a weak frontal passage on the 10th, which brought a cold air mass to the Valley, this air remained trapped within the Valley boundary layer resulting in strong surface based inversions. Coupled with the synoptic and surface pattern, which was indicative of light and disorganized wind flow, PM became a region-wide problem until a weak trough scoured out the area on New Year's Eve. As is evident in the PM data, local and regional emissions contributed to the exceedance of the NAAQS at Corcoran on the 17th and Fresno-Drummond, and Hanford on the 23rd. If monitoring were done on a daily basis, more exceedances would have been recorded during this time frame at other San Joaquin Valley locations. Event #2 ended when a cold front from the Gulf of Alaska moved through the region bringing enhanced dispersion across the San Joaquin Valley, lowering pollutant levels to below the PM_{2.5} NAAQS.

Event #3 January 1 through January 12, 2000:

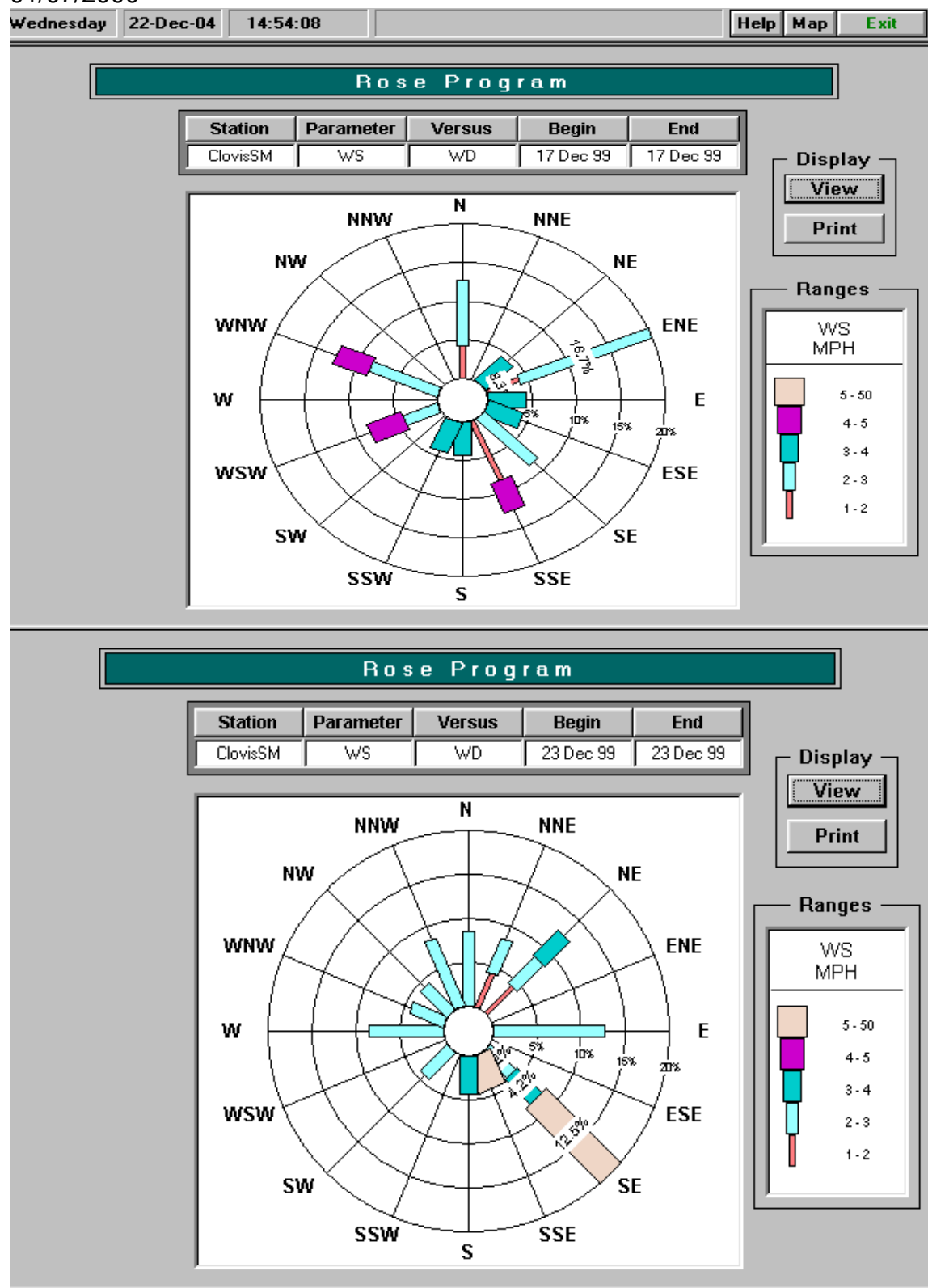
Meteorologically, dispersion once again worsened and particulate conditions became more favorable from January 1st to January 10th. As is evident in Figure #2, event #3 lasted about 12 days and was marked by multiple violations of the PM_{2.5} NAAQS. After the passage of a weak cold front on January 1, 2000, which brought trace amounts of precipitation to the San Joaquin Valley, moisture became available for atmospheric

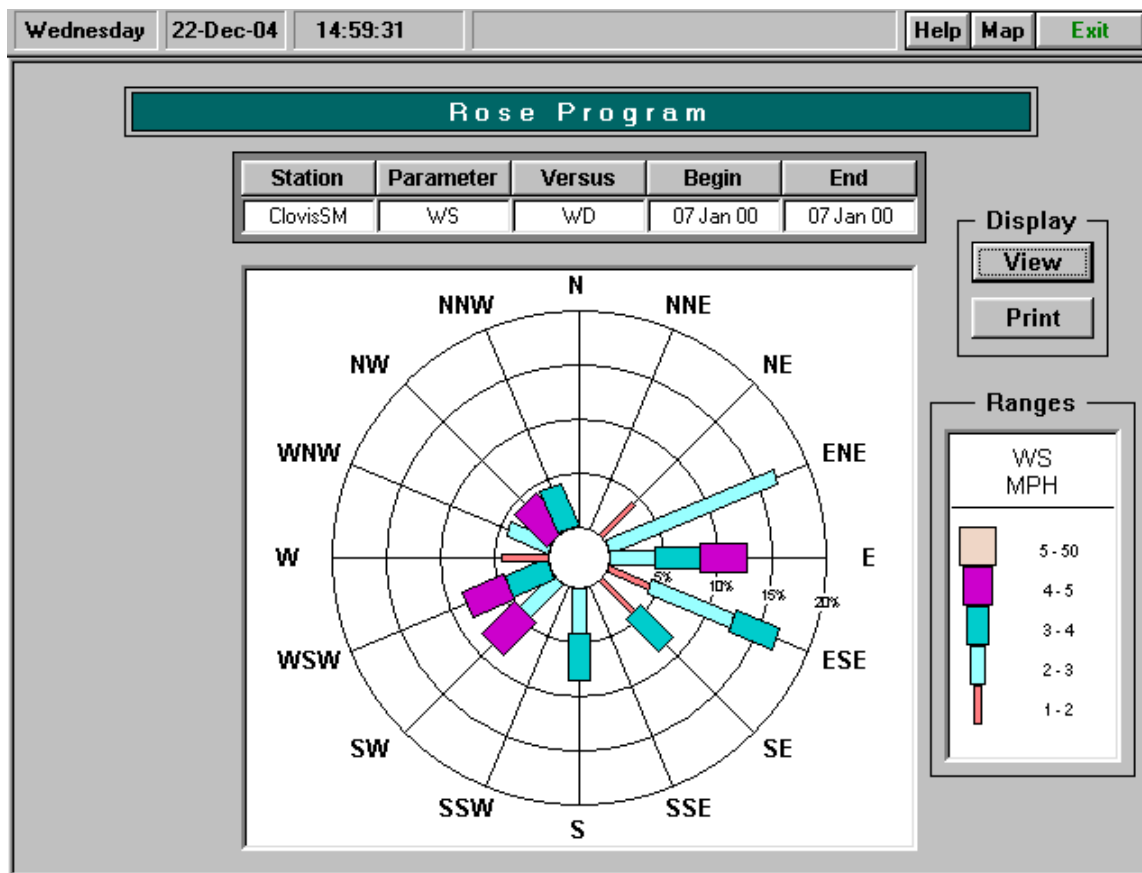
chemistry reactions. Humidity measurements of 85 – 100 % in the morning across the Valley Floor showed a moist air mass, with light fog and haze being reported.

Synoptically, during event #3 a weak ridge dominated along the California Coastline directing upper level disturbances into the Pacific Northwest. The ridge was strong enough to gradually, through a period of a few days, cause a localized PM_{2.5} problem centered at the urban areas, which spread outward toward the rural areas and become a regional problem, especially across the central and southern parts of the San Joaquin Valley. The fast upper level flow pattern was positioned over the Pacific Northwest through event #3, with multiple embedded disturbances within this flow. California remained on the southern periphery (stable side) of this flow pattern. With a moderate lid in place aloft and maximum temperatures in the mid to upper 50's, the afternoon hours were marked by limited mixing, resulting in increasing particulate potential. Mixing heights at Fresno remained below 500 feet under a moderate inversion during most of the day (16 hours or more). During the afternoon hours there were moderate mixing depths of 1,500 to 2,000 feet but the bulk of the day had limited mixing. Maximum and minimum temperatures were near or slightly below normal, indicating a potential for higher residential wood burning emission activity and nitrate forming reactions.

Meteorological data during event #3 showed limited mixing depths and light north to northwesterly wind flow resulted in minimal dispersion of pollutants. Both primary and secondary pollutants from local emissions across the metropolitan areas of the San Joaquin Valley accumulated resulting in an exceedance of the 24 hour PM_{2.5} NAAQS at several sites on January 7, 2000. These sites included: Merced, Chowchilla, Fresno-1st, Clovis-Villa, Selma, Visalia-Church, Corcoran-Patterson, Kettleman, Pixley Wildlife Refuge, Oildale, and Bakersfield Golden and California. Since both rural and urban areas registered PM_{2.5} levels above the NAAQS, these violations continued through the 10th of January at most locations. A dry cold front moved through the region on January 12, 2000, providing adequate northwesterly flow, resulting in PM_{2.5} levels lowering below the NAAQS.

Figure 29: Wind Rose at Clovis Air Monitoring Site for 12/17 and 12/23/1999, and 01/07/2000



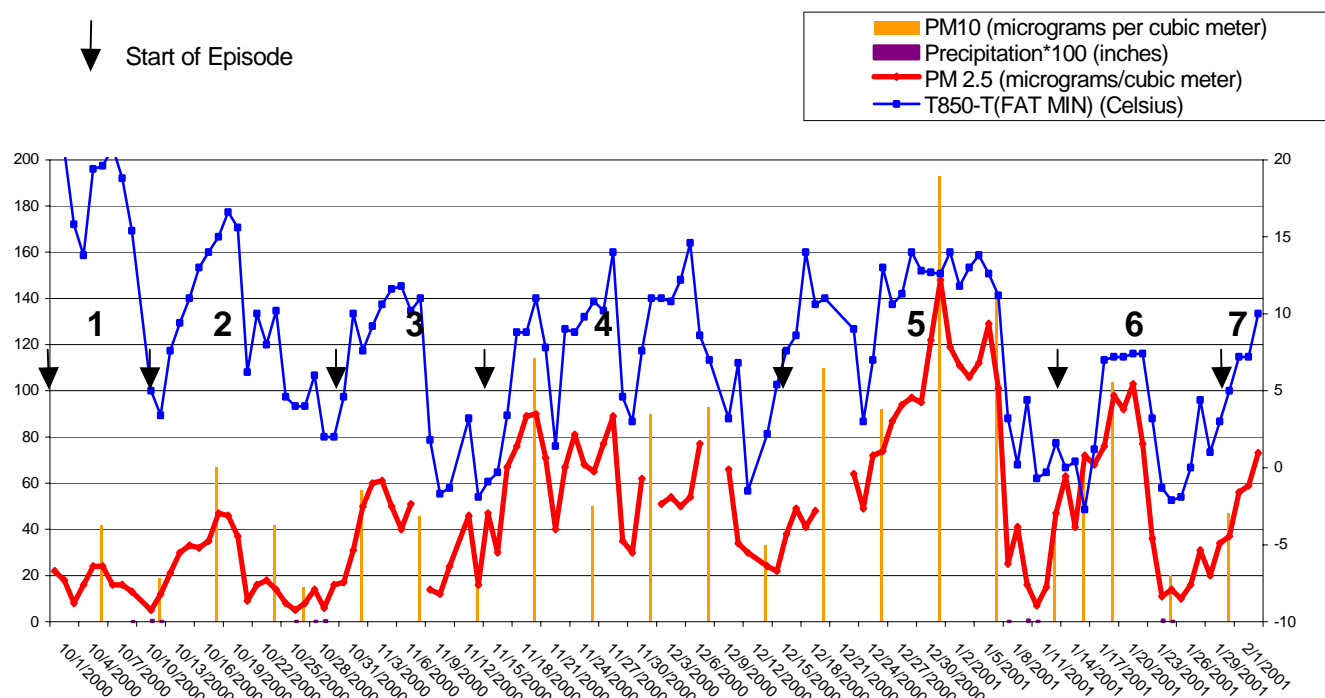


11.0 DECEMBER 2000 AND JANUARY 2001 EPISODE SYNOPTIC METEOROLOGICAL DISCUSSION

The CRPAQS fall and winter measurement periods can be divided into seven distinct episodes. These episodes, characterized by limited atmospheric dispersion, were separated by vigorous trough passages. Analysis of synoptic events shows that once a particulate episode begins, a deep trough must traverse the region at both the upper levels of the atmosphere and at the surface as a cold frontal boundary in order to significantly decrease Particulate Matter (PM) concentrations. These types of troughs are normally associated with strong vertical mixing, moderate to high boundary layer mixing heights, precipitation, and wind speed and directional shear within the boundary layer.

The meteorological analysis for CRPAQS utilized synoptic analyses, precipitation patterns, and atmospheric stability parameters to determine episode strength and periodicity. Analysis of $PM_{2.5}/PM_{10}$ ratios and nitrate levels reveal that when the overnight minimum temperature decreased to below 40 degrees Fahrenheit, coupled with significant warming aloft, fine particulate levels climbed. When prolonged periods of these conditions occurred, $PM_{2.5}$ levels climbed above the NAAQS. In even stronger more persistent stability regimes, PM_{10} exceeded the NAAQS. **Figure 30** shows precipitation, $PM_{2.5}$, PM_{10} , and stability parameters for the CRPAQS period at the Fresno-1st site. General patterns in these parameters were also evident at other sites. Precipitation events also influenced PM concentrations during CRPAQS. For the CRPAQS period, when a frontal system was strong enough to produce precipitation of 0.10 inch or more of liquid water, 24 hour averaged $PM_{2.5}$ concentrations dropped to below $15 \mu\text{g}/\text{m}^3$.

Figure 30: Fresno-1st Stability and Pollutant Trends for Fall 2000 & Winter 2001



The synoptic meteorological parameters analyzed to determine the behavior of particulate matter were 850 MB temperature stability (T850 Stability $^{\circ}\text{C}$), 500 MB height (decameters), and precipitation (inches). The 850 MB temperature stability parameter was utilized because 850 MB temperature (approximately 5,000 feet) minus the minimum surface temperature is a good indicator of the inversion strength, the mixing layer depth, and whether air is being warmed from a synoptic subsidence inversion aloft. This inversion is commonplace when a ridge builds along the West Coast of California, providing general adiabatic warming of subsiding air over the region. In Hackney, et al, an analysis was conducted on the relationship of historical 850 MB temperatures and PM measurements. Hackney, et al, determined that in the San Joaquin Valley, when 850 MB temperatures in the fall were above $+15^{\circ}\text{C}$ and $+10^{\circ}\text{C}$ during the winter (late November or December to February) an episode was possible. A stronger indication for a PM episode to occur is when 850 MB temperatures were above $+18^{\circ}\text{C}$ in the fall and above $+14^{\circ}\text{C}$ in the winter.

500 MB height is also important in that it is directly correlated to the temperature of the entire column of air. During periods of high pressure aloft, flows at the surface are usually light and accompanied by low mixing depths. The 500 MB height and placement of the mean ridge and trough patterns reflect PM amounts and trends. In Hackney, et al, it was determined that a height of 5,760 meters in the San Joaquin Valley is sufficient to suspect an episode, and that a height of 5,820 meters or more in the Valley made an episode occurrence a likelihood.

Precipitation measurements were also analyzed as an indicator of the vigorous trough passages, which provided enough vertical mixing to produce rainfall. As mentioned before, the strength of the frontal system and trough, was a good indicator of how much PM dispersion occurred.

Table 19 shows for each peak day within the seven episodes, the PM values, meteorological parameters, and episode duration. The major episode of CRPAQS, when PM₁₀ exceeded the NAAQS, was manifested by cool overnight lows near 32 degrees Fahrenheit and warm air aloft for an extended period of time. These conditions persisted from December 17th through January 7th. During this time, PM steadily increased to a peak value at Fresno (PM_{2.5} = 148 µg/m³ and PM₁₀ = 193 µg/m³) and Bakersfield-Residential (PM_{2.5} = 133 µg/m³) on the 1st of January. During this period in urban areas, initial analysis of speciation data show high carbon and ammonium nitrate levels. The combination of an 850 MB temperature ridge aloft along with low minimum temperatures resulted in strong inversions trapping pollutants in a shallow mix layer. The high carbon levels could have been due to holiday residential wood combustion. In addition, under these cold and poor dispersion conditions, nitrate levels measured on the real-time instruments were the highest of the study.

TABLE 19: CRPAQS EPISODE EVENT SUMMARY TABLE AT FRESNO

Episode Number	Date	Peak PM ₁₀ (µg / m ³)	Peak PM _{2.5} (µg / m ³)	T850 Stability (°C)	Minimum (°F)	500 MB Height (dm)	Episode Duration (days)
1	10/1-10/12/00	42(6 th)	24 (5 th & 6 th)	2.4	63	578	12
2	10/13-10/30/00	67(18 th)	47 (18 th)	6.8	54	578	18
3	10/31-11/15/00	57 (2 nd)	61 (4 th)	2.3	47	575	17
4	11/16-12/15/00	114 (20 th)	90 (20 th) 89 (28 th)	9.3 6.2	35 46	576 572	28
5	12/16/00-01/12/01	193 (1 st)	148 (1 st)	12.6	32	574	26
6	01/13-01/27/01	104 (19 th)	103(21 st)	3.9(19 th) 6.8(21 st)	38 (19 th) 33 (21 st)	571(19 th) 569(21 st)	15
7	01/28-02/03/01	47 (31 st)	73 (3 rd)	3.9(31 st) 6.1(3 rd)	34 (31 st) 39 (3 rd)	568(31 st) 580(3 rd)	7

One basis for understanding the behavior of particulate matter evolution is to analyze the synoptic situation that is driving the local effects of dispersion and transport. These synoptic descriptions follow.

Episode 1: Sunday, October 1 -Thursday, October 12

From the 1st to the 8th, episode #1 was marked by a mean, broad ridge anchored across the eastern Pacific and California, which brought moderate stability and low to moderate mixing heights. This ridge was low in amplitude, resulting in moderate subsidence. An inverted thermal surface trough developed from Bakersfield curving northwestward to Redding. This pressure pattern was representative of calm overnight winds, and thermally driven light afternoon northwesterly flow. During this initial episode, PM_{2.5} values average near 20 µg/m³ and measured PM₁₀ concentration at Fresno was 42 µg/m³ on the 6th. The 500 MB height of 578 dm on the 6th was conducive of a high PM event, whereas, the 850 MB stability parameter of +2.4 Celsius (T850 MB = +20⁰C) was indicative of the likelihood of an event. As is evident in the low T850 MB stability parameter, the inversion and resulting stability was not strong enough to trap and elevate PM readings, thus resulting in PM levels remaining well below the standard.

A significant early season trough moved into the region on the 9th, bringing increasing instability and boundary layer flow. Within the next couple of days, the 9th to the 12th, a series of disturbances embedded within the mean trough traversed central California bringing increased wind flow, higher boundary layer mixing heights, and precipitation. The most noteworthy precipitation during this period occurred on the 11th, when a second short wave embedded within the mean trough across California crossed the Valley and produced 0.76 inches of precipitation.

Episode 2: Friday, October 13 –Monday, October 30

Episode #2 was marked by high pressure rapidly building into the region on the 13th and persisting through the 20th. This episode was unique in that the central California was under the influence of both the eastern Pacific and Four Corners ridge during the peak episode day. This pattern resulted in weak thermally driven flow at the surface and general synoptic subsidence aloft. As a result, under light to moderate stability, T850 stability parameter of +2.8 ⁰C (T850 MB = 15⁰C), moderately high 500 MB heights (578 MB) and low mixing depths, PM climbed and reached a maximum concentration in Fresno at PM₁₀ – 67 µg/m³ and PM_{2.5} – 47 µg/m³ and Bakersfield at PM_{2.5} – 30 µg/m³ on the 18th. According to Hackney, et, al, the 850 MB temperature and 500 MB heights reached the criteria to suspect an episode. As is evident in the PM measurements the state standard was exceeded in Fresno on the 18th.

The ridge began to breakdown on the 20th as weak disturbances traversed the ridge and formed a closed low over the Great Basin on the 24th. Another stronger trough moved into the region on the 25th bringing moderate boundary layer flow, vigorous vertical mixing, and periods of precipitation through the 30th. With the trough passage on the 29th, Fresno recorded the maximum amount of precipitation during the episode of 0.55 inches.

Episode 3: Tuesday, October 31 –Wednesday, November 15

Episode #3 began on the 31st as a strong ridge developed along the West Coast. The ridge axis remained offshore during this episode leading to downstream subsidence and increasing stability. During the peak PM event of episode #3, Bakersfield's PM values were lower than Fresno due to a closed low circulation over northern Baja, creating some upper level mixing and neutral to light instability over southern California. As a result, the peak PM_{2.5} levels at Bakersfield Residential were 45 µg/m³, with a T850 MB stability parameter of +1.4 °C (T850 MB = +9.2 °C) and 500 MB height of 575 dm on the 3rd and at Fresno First PM₁₀ measurement of 57 µg/m³ on the 2nd and PM_{2.5} measurement 61 µg/m³, with a 850 MB stability parameter of +2.3 °C (T850 MB = +10.6 °C) and 500 MB height of 575 dm on the 4th.

In both Fresno and Bakersfield, according to Hackney et, al, the T850 MB and 500 MB heights do not suggest an episode under a fall regime; however, the PM₁₀ measurement in Fresno exceeded the standard on the 2nd. Whereas, comparing Hackney et, al, results under a winter regime to the observed T850 MB, their conclusion supported a minor PM episode. Due to early season rainfall and a general cooling of the lower levels of the atmosphere, the transition from the fall to the winter regime took place during this time.

PM levels steadily lowered as the upper level ridge and surface high pressure gradually weakened and moved eastward. An unseasonably cold trough (540 dm at OAK) and a vigorous, dry cold front from the Gulf of Alaska moved into the region on the 9th, bringing increased boundary layer flow and deep mixing. This system was moisture starved and resulted in trace amounts of precipitation across the region. The frontal system and accompanying trough were strong enough to bring an end to the 3rd episode as deep mixing scoured the area. Multiple embedded disturbances within this trough traversed the region bringing unstable conditions, good dispersive conditions, and moderate boundary layer flow and mixing heights into the 15th.

Episode 4: Thursday, November 16 –Friday, December 15

Episode #4 began on the 16th and was marked by a moderate ridge building along the West Coast bringing increasing stability and offshore flow. During CRPAQS the 4th episode was the longest period at 28 days.

Stability and PM values steadily increased to the highest measured values of the episode on the 20th and 21st of November, with a secondary peak occurring on the 28th. This episode was separated into two peaks due to a trough developing over the Great Basin on the 22nd dispersing some of the PM which had built up over the region. Fresno and Bakersfield peak PM_{2.5} measurements were observed on the 20th at 90 µg/m³ and on the 21st at 96 µg/m³, respectively. The highest measured PM₁₀ during this episode was at Fresno on the 20th with a value of 114 µg/m³. Fresno PM_{2.5} measurement reached a secondary peak on the 28th at 89 µg/m³. This episode was separated into two peaks due to a trough developing over the Great Basin on the 22nd dispersing some of the PM which had built up over the region.

According to Hackney, et., al, the 850 MB temperature measured $+11^{\circ}\text{C}$ and $+14^{\circ}\text{C}$ on the 20th and 28th, respectively, were representative of an PM episode occurring, whereas, the 500 MB heights of 576 and 572 dm, were indicative of a weak PM episode. During this episode, the state standard was exceeded.

This episode was characterized by a mean mid-tropospheric ridge positioned along the West Coast, with brief drop in the PM measurements on the 29th and 30th, when a dry, front passed to the north of the area dropping to PM_{2.5} measurements at Fresno to $35\text{ }\mu\text{g}/\text{m}^3$ on the 30th and Bakersfield to $22\text{ }\mu\text{g}/\text{m}^3$ on the 29th.

The ridge began to breakdown late on the 7th, bringing decreasing stability, better dispersion, and lowering PM concentrations. A series of weak disturbances traversed the region from the 7th through the 15th, bringing very light precipitation to Fresno (total = 0.07 inches), increased boundary layer flow and mixing depths, which brought an end to the episode #4.

Episode #5: Saturday, December 16 –Friday, January 12

Episode #5 began on the 16th and was marked by the West Coast ridge building into California, resulting in lowering boundary layer mixing heights and increasing stability. PM region-wide uniformly increased with 500 MB heights and stability, with a minor intra-episode peak, with PM₁₀ measurement at Fresno of $110\text{ }\mu\text{g}/\text{m}^3$ and PM_{2.5} measurement at Bakersfield Residential of $58\text{ }\mu\text{g}/\text{m}^3$, occurring on the 20th. A weak upper level disturbance briefly broke down the ridge on the 24th resulting in slightly lower PM_{2.5} measurements in Fresno at $49\text{ }\mu\text{g}/\text{m}^3$ and Bakersfield $40\text{ }\mu\text{g}/\text{m}^3$. After this weak trough passage, the ridge rebuilt in earnest and moderate stability and low mixing heights continued through the end of the episode on January 7th.

During this episode the maximum PM measurements of the CRPAQS period were observed. The general synoptic pattern during this episode was strong high pressure aloft positioned along the West Coast providing a general area of subsidence and stable weather over the region, with an accompanying strong surface high located over Idaho. With high pressure over the Intermountain Region and lower pressures over the eastern Pacific, moderate offshore flow developed. Typically with this type of flow pattern, the normal nocturnal inversion at the surface is reinforced with a subsidence inversion aloft, created by adiabatic warming off the Sierra's and general subsidence from the ridge.

The peak measurements of the fifth episode were recorded on the 1st and 7th with PM₁₀ measurements at Fresno of $193\text{ }\mu\text{g}/\text{m}^3$ (1st) and $141\text{ }\mu\text{g}/\text{m}^3$ (7th). PM_{2.5} measurements at Fresno of $148\text{ }\mu\text{g}/\text{m}^3$ (1st) and $101\text{ }\mu\text{g}/\text{m}^3$ (7th) and Bakersfield Residential at $133\text{ }\mu\text{g}/\text{m}^3$ (1st) were also recorded. These high PM values corresponded with the highest 850 MB stability ($+13.4\text{ }^{\circ}\text{C}$ at Oakland) measured during the CRPAQS period, which occurred on the 2nd. The 850 MB temperature was very warm during this episode. At Oakland at 12Z, the 850 MB temperature was $+13\text{ }^{\circ}\text{C}$. This is representative of a strong PM episode. The 500 MB height was not indicative of a strong episode. At 574 dm, the value was not conducive to a significant PM episode. The combination of weak offshore

flow and mid-tropospheric stability, elevated the PM readings experienced across central California.

A significant trough moved into the region on the 8th, with accompanying rainfall in Fresno of 0.31 inches and Bakersfield of 0.29 inches. A series of disturbances within the trough traversed the region from the 8th to the 12th adequately dispersing the PM that had built up over the region during the episode and lowered PM_{2.5} measurements into the upper teens by the 10th in both Fresno and Bakersfield.

Episode 6: Saturday, January 13 –Saturday, January 27

High pressure and increasing subsidence once again moved into the region on the 13th bringing increasing PM levels and leading to the beginning of the episode #6. This episode was characterized by ridging through the 17th, resulting in building PM_{2.5} values into the lower 60's $\mu\text{g}/\text{m}^3$ range. Shortly thereafter, more pronounced ridging and decreasing dispersion occurred on the 18th, when 500 MB heights climbed to near 578 dm with an 850 MB stability indices of +7 °C (850 MB temperature of +7°C). The 500 MB height was conducive of an episode occurring, but the 850 temperature was not conducive of an episode. This peak in meteorological parameters corresponded with the highest recorded PM₁₀ measurement of the episode at Fresno at 104 $\mu\text{g}/\text{m}^3$ on the 19th.

PM_{2.5} peaked at Fresno on the 21st with a measurement of 103 $\mu\text{g}/\text{m}^3$ and also in Bakersfield Residential on the 22nd at 103 $\mu\text{g}/\text{m}^3$. The southward progression of the peak PM_{2.5} values can be accounted for by the pre-frontal / trough stability that progressively moved down-valley with the approach of the next system from the eastern Pacific on the 23rd.

A series of disturbances embedded within the trough moved through the region from the 23rd to the 27th, with adequate boundary layer mixing heights, moderate instability, and moderate southeasterly flow, dispersing PM levels into the low teens. From the 23rd to the 25th, a series of strong cold frontal systems brought 1.19 inches of rainfall at Fresno, bringing an end to the 6th episode. The highest recorded rainfall during the trough passage occurred on 0.85 inches on the 24th.

Episode 7: Sunday, January 28 –Saturday, February 3

The final (7th) episode of CRPAQS began on the 28th, when strong high pressure built along the West Coast. Light boundary layer flow and increasing 850 MB stability resulted in PM_{2.5} levels gradually climbing into the early part of February. PM_{2.5} measurements of 73 $\mu\text{g}/\text{m}^3$ in Fresno on the 3rd and 92 $\mu\text{g}/\text{m}^3$ in Bakersfield on the 4th marked the buildup that occurred during this episode.

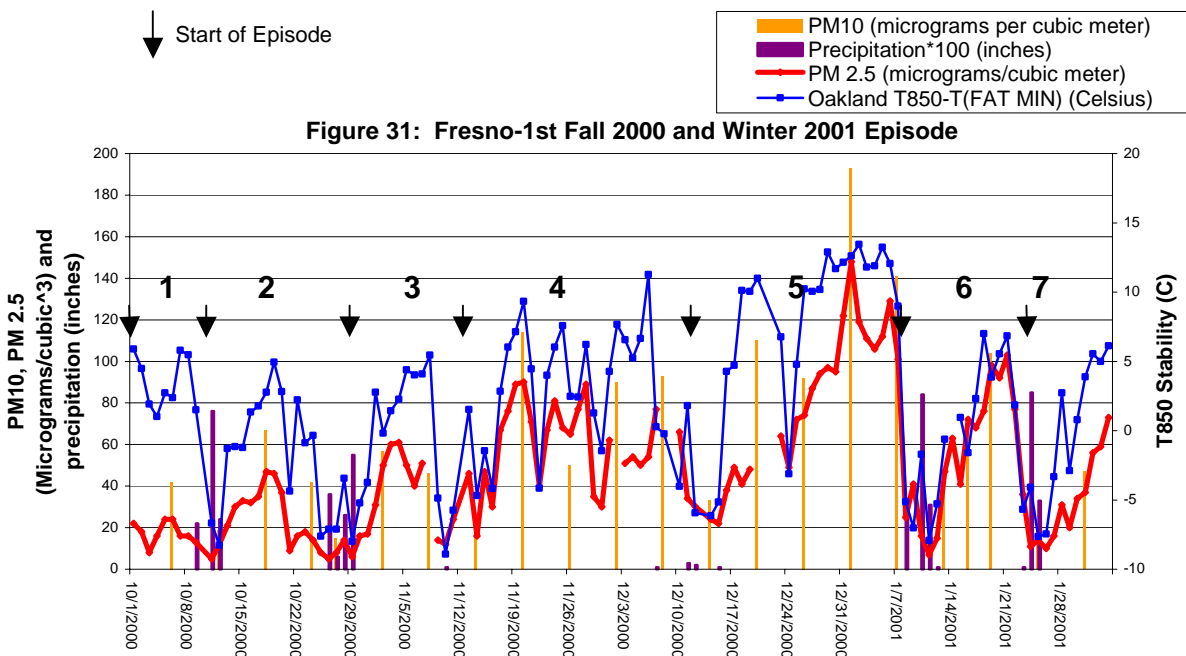
12.0 DISPERSION METEOROLOGY FOR THE FALL 2000 AND WINTER 2001 CALIFORNIA REGIONAL PM₁₀/PM_{2.5} AIR QUALITY STUDY EPISODE

During the Fall 2000 and Winter 2001 episode, strong high pressure at the surface and aloft resulted in limited morning and afternoon mixing and light offshore wind flow. Cool damp mornings and strong stability contributed to the formation of nitrates and sulfates during the episode. The California Regional Particulate Air Quality Study (CRPAQS) fall and winter measurements can be divided into seven distinct events. These events, characterized by limited atmospheric dispersion, were separated by vigorous trough passages. Analysis of synoptic patterns shows that once a particulate period begins, a deep trough must traverse the region at both the upper levels of the atmosphere and at the surface as a cold frontal boundary in order to significantly decrease particulate matter (PM) concentrations. These types of troughs are normally associated with strong vertical mixing, moderate to high boundary layer mixing heights, precipitation, and wind speed and directional shear within the boundary layer.

The meteorological analysis for CRPAQS utilized synoptic analyses, precipitation patterns, and atmospheric stability parameters to determine episode strength and periodicity. Analysis of PM_{2.5}/PM₁₀ ratios and nitrate levels reveal that when the overnight minimum temperature decreased to below 40 degrees Fahrenheit, coupled with significant warming aloft, fine particulate levels climbed. When prolonged periods of these conditions occurred, PM_{2.5} levels climbed above the National Ambient Air Quality Standards (NAAQS). In even stronger more persistent stability regimes, PM₁₀ exceeded the NAAQS. **Figure 31** shows precipitation, PM_{2.5}, PM₁₀, and stability parameters for the CRPAQS period at the Fresno-1st site. General patterns in these parameters were also evident at other sites. Precipitation influenced PM concentrations during CRPAQS. For the CRPAQS episode, when a frontal system was strong enough to produce precipitation of 0.10 inch or more of liquid water, 24 hour averaged PM_{2.5} concentrations dropped to below 15 µg/m³. Seven distinct events were identified when particulate levels lowered to near background levels.

Each event was marked by limited mixing heights with strong inversions of approximately 500 feet for 18 or more hours of the day. Maximum mixing depths of highest PM_{2.5} concentration days ranged between 1,500 to 2,500 feet. Moisture availability from recent rainfall and minimal solar insulation, led to prime nitrate and sulfate forming conditions. Typically, light fog, with humidity measurements between 85 – 100% were needed in order to maximize particulate forming potential. The higher the humidity, the heavier and wetter the fog, resulted in the removal of particulates by wet deposition.

Within these seven distinct measurement periods, a violation of the Federal 24 hour PM_{2.5} standard of 65 micrograms/cubic meter were recorded during the 4th, 5th, 6th, and 7th events at various locations across the San Joaquin Valley. The following analysis will investigate the meteorological and dispersion conditions surrounding each event.



Event #4: November 16 through December 14, 2000

Meteorologically, dispersion worsened and particulate formation conditions became more favorable from November 16th to December 10th. As is evident in **Figure 31**, event #4 lasted about 28 days and was marked by two main PM_{2.5} peaks, which exceeded the Federal Standard. After the passage of a weak cold front on November 14, 2000, which brought a trace to a few hundredths of an inch of precipitation across the region, moisture became available for atmospheric chemistry reactions. Humidity measurements of 90 – 100 % in the morning across the Valley Floor showed a moist atmosphere, with light fog and haze being reported on measured high PM_{2.5} days. These cool damp mornings and strong stability favored the formation of nitrates and sulfates. It does not appear that the water content of the atmosphere was high enough to create deposition of particles that exceeded formation.

Synoptically during the first part of event #4, the eastern Pacific high built over the Pacific Northwest on November 17th then expanded southward on the 18th, bringing increasing stability and poor dispersion conditions through November 30th. From November 17th through the 30th, the high strengthened and intensified on November 19th through the 20th and once again on November 24th through the 28th, further tightening the lid and trapping the pollutants within the San Joaquin Valley boundary layer.

With a strong lid in place aloft and maximum high temperatures in the upper 50's to low 60's on the 19th and 20th, and upper 40's to low 50's on the 24th through the 27th, the afternoon hours were marked by limiting mixing, resulting in increasing particulate potential. Mixing heights at Fresno remained below 500 feet under a strong inversion

during a majority of the day (18 or more hours) on days when the fine particulates climbed above the standard. During the afternoon hours, there were high mixing depths (maximum mixing depth of 1,500 to 2,500 feet), but the bulk of the day had limited mixing. Maximum and minimum temperatures from November 19th through the 27th, were below normal, indicating a potential for increasing residential wood burning emission activity, and nitrate forming reactions.

Light fog and haze were reported at the Valley surface during the early morning hours of November 19th through the 27th, resulting in slightly lower solar radiation intensities. Along with lower solar radiation intensities due to the early morning fog and haze, low sun angle, and reduced daylight hours, the atmospheric chemistry reactions may have favored the secondary particulate forming regime. Light fog would be indicative of moderate atmospheric water content that contribute to the formation of ammonium nitrate. Heavier fogs result in the removal of particulates by wet deposition.

Meteorological data during the first part of event #4 showed limited mixing depths and light and disorganized wind flow resulted in minimal transport and dispersion of pollutants. Both primary and secondary pollutants from local emissions across the San Joaquin Valley accumulated resulting in the exceedance of the 24-hour PM_{2.5} standard at Fresno-1st on November 19th, Modesto 14th, Clovis-Villa, Fresno-1st, Visalia-Church, Corcoran-Patterson, Oildale, Bakersfield-Golden and California on November 20th, Bakersfield-California on November 21st, Fresno-1st on November 24th, Bakersfield-California on November 25th, Bakersfield-Golden and California on November 26th, Bakersfield-California on November 27th, and Clovis-Villa, on November 28th.

A dissipating cold front moved over the San Joaquin Valley on the 29th, bringing an end to the first part of event #4 that lasted from November 16th through the 30th. The disturbance brought moderate dispersion conditions across the Valley, allowing for pollutants to lower into the 25 to 30 micrograms per cubic meter range, but was not significant enough to drop PM_{2.5} levels to background.

High pressure rebuilt over the region on December 1st, leading to the second part of event #4. Meteorologically, dispersion rapidly deteriorated and particulate formation conditions became more favorable on December 2nd. Humidity measurements of 90 – 100 % in the morning across the Valley Floor showed a continued moist atmosphere, with light fog and haze being reported on measured high PM_{2.5} days. These cool damp mornings and strong stability favored the formation of nitrates and sulfates.

Synoptically during the second part of event #4, the eastern Pacific high built along the West Coast on the 1st then expanded eastward on the 2nd, bringing increasing stability and poor dispersion conditions through the end of event # 4 on December 12. During this period, the high strengthened and intensified on December 2nd and once again on December 8th through the 10th, further tightening the lid trapping the pollutants within the San Joaquin Valley boundary layer.

With a strong lid in place aloft and maximum high temperatures in the upper 40's to low 50's, the afternoon hours of December 2nd through the 8th were marked by limiting mixing, resulting in increasing particulate potential. Mixing heights at Fresno remained below 500 feet under a strong inversion during a majority of the day (18 or more hours) on days when the fine particulates climbed above the standard. During the afternoon hours, there were high mixing depths (maximum mixing depth of 1,000 to 2,500 feet), but the bulk of the day had limited mixing.

Maximum and minimum temperatures from December 2nd through the 5th were slightly below normal and from December 7th to the 12th were above normal. Light fog and haze were reported at the Valley surface during the early morning hours of December 2nd through the 10th, resulting in slightly lower solar radiation intensities. Along with lower solar radiation intensities due to the early morning fog and haze, low sun angle, and reduced daylight hours, the atmospheric chemistry reactions may have favored the secondary particulate forming regime. Light fog would be indicated of moderate water content's that contribute to the formation of ammonium nitrate. Heavier fogs result in the removal of particulates by wet deposition.

Meteorological data during the second part of event #4 showed limited mixing depths and light and disorganized wind flow resulted in minimal transport and dispersion of pollutants. Daily filter measurements at Bakersfield-California and Fresno-1st indicated that between December 3rd and 4th, PM_{2.5} levels dropped below the PM_{2.5} standard in response to heavy fog, which lead to the removal of particulates by wet deposition. However, on the 7th and 8th the fog lifted to low clouds across the San Joaquin Valley causing both primary and secondary pollutants from local emissions across the region to accumulate resulting in the exceedance of the 24-hour PM_{2.5} standard at various monitoring sites from December 5th through the 10th. An exceedance of the 24-hour PM_{2.5} standard were measured at Bakersfield California on December 5th through the 10th, Modesto-14th, Clovis-Villa, Fresno 1st, Visalia, Corcoran, Oildale, Bakersfield-Golden, and Edison, on December 8th, and Fresno 1st on December 9th. A moderate cold front traversed over the San Joaquin Valley on December 11th bringing upwards to 0.05 to 0.10 of an inch of precipitation across different parts of the District. This frontal passage brought moderate dispersion conditions across the Valley, allowing for pollutants to lower to near background levels bringing an end to event #4.

Event #5: December 15, 2000 through January 11, 2001

Meteorologically, dispersion worsened and particulate formation conditions strengthened from December 10th to January 7th. As is shown in **Figure 31**, event #5 lasted about 27 days and was marked by a gradual buildup of PM_{2.5} that lead to multiple days the Federal PM_{2.5} Standard was exceeded. During event #5, strong high pressure at the surface and aloft resulted in limited afternoon mixing and light offshore wind flow. Cool damp mornings and strong stability contributed to the formation of nitrates and sulfates during the episode.

After the passage of a cold front on December 11, 2000, which brought a few hundredths of an inch of precipitation to the region, moisture became available for atmospheric chemistry reactions. Humidity measurements of 90 – 100 % in the morning across the Valley Floor showed a moist atmosphere, with light fog and haze being reported on the exceedance days. These cool damp mornings and strong stability favored the formation of nitrates and sulfates.

Synoptically during event #5, the eastern Pacific high built over the San Joaquin Valley on December 12, 2000 and dominated the region's weather through January 7, 2001. The event was divided into two periods from December 15 through December 24, 2000 and December 24, 2000 to January 11, 2001. A trough moved into northern California on December 24, allowing for slightly better dispersion conditions and a decrease in fine particulate levels across the San Joaquin Valley.

High pressure gradually intensified over the San Joaquin Valley between December 12th through the 20th, leading to PM_{2.5} levels exceeding the National Ambient Air Quality Standards on December 20th at Fresno-1st. However, by December 22 a weak trough moved into northern California providing improving dispersion conditions across the San Joaquin Valley and lowering fine particulate measurements to below the National and California Ambient Air Quality Standards.

By December 25th, the combination of increased local emissions due to the Christmas and New Year Holiday's and intensifying stability aloft initiated an eleven day stretch where numerous sites across the San Joaquin Valley exceeded the PM_{2.5} Standard. These violations began in the urban areas of Fresno, Modesto, and Bakersfield and spread regionally into the rural sections by the end of the episode on January 7. The meteorology surrounding this event were classified as an intense high dominating central California's air quality, leading to strong stability and light wind flow.

With a strong lid in place aloft and maximum high temperatures in the upper 50's to low 60's, the afternoon hours were marked by limited mixing, resulting in increasing particulate potential. Mixing heights at Fresno remained below 500 feet under a strong inversion for 19 hours on January 1st, breaking out after 4:00 P.M and reforming shortly after 7:00 P.M. During the afternoon hours, there were higher mixing depths (maximum mixing depth of 1,000 feet), but the bulk of the day had limited mixing.

Maximum and minimum temperatures for the exceedance day were slightly above normal, further illustrating the intensity of the high pressure system that was controlling the region's weather. Light fog was reported at the Valley surface during the early morning hours of January 1st, resulting in slightly lower solar radiation intensities. Along with lower solar radiation intensities due to the early morning fog, low sun angle, and reduced daylight hours, the atmospheric chemistry reactions may have favored the secondary particulate forming regime. Light fog would be indicative of moderate water content's that favor the formation of ammonium nitrate. Heavier fogs result in the removal of particulates by wet deposition. Chemical composition and meteorological

data showed limited mixing depths and light and disorganized wind flow resulted in minimal transport and dispersion of pollutants.

Meteorological conditions remained extremely stable between January 1st through the 4th, leading to elevated fine particulate conditions continuing across the San Joaquin Valley. Without a significant weather disturbance moving through the area to scour out the particulates, PM_{2.5} concentrations continued to climb and exceeded the NAAQS at multiple urban and rural monitoring sites on January 4th.

With a strong lid in place aloft and maximum high temperatures in the low 60's, the afternoon hours on January 4th, were marked by limited mixing, resulting in increasing particulate conditions. Mixing heights at Fresno remained below 500 feet under a strong inversion for 20 hours on January 4th. During the afternoon hours, there were higher mixing depths (maximum mixing depth of 2,000 feet), but the bulk of the day had limited mixing.

Maximum temperatures for this exceedance day were above normal, further illustrating the intensity of the high pressure system that was controlling the region's weather. Light fog reported at the Valley surface during the early morning hours, resulted in slightly lower solar radiation intensities. Along with lower solar radiation intensities due to the low sun angle and reduced daylight hours, the atmospheric chemistry reactions may have favored the secondary particulate forming regime. Meteorological data showed limited mixing depths and light and disorganized wind flow resulted in minimal transport and dispersion of pollutants. The following day, January 5th, PM_{2.5} measurements recorded the highest levels during event #5.

Between January 5th and January 7th, meteorological conditions began to slowly improve leading to slightly lower but continued elevated particulate conditions across the San Joaquin Valley. Without a significant weather disturbance moving through the area to scour out the fine particulates, PM_{2.5} and PM₁₀ concentrations continued to remain high and exceeded the Federal Standard, (**Table 20 and Figure 32, 33, 34, and 35**). Humidity measurements of 85 – 100 % on the morning of January 7th, across the Valley Floor showed a relatively moist atmosphere, with light fog and haze being reported. The cool damp mornings and strong stability favored the formation of nitrates and sulfates. Synoptically, the eastern Pacific high began to slowly weaken and move into the Intermountain Region on January 7, 2001, slightly weakening the lid over the San Joaquin Valley.

On January 7th a moderately strong lid was in place aloft and maximum high temperatures were in the mid 60's. The afternoon hours were marked by limited mixing, resulting in elevated particulate conditions. Mixing heights at Fresno remained below 500 feet under a strong inversion for 16 hours on January 7th. During the afternoon hours, there were higher mixing depths (maximum mixing depth of 2,000 feet), but the bulk of the day had limited mixing. Maximum temperatures for this exceedance day were above normal, further illustrating the intensity of the high pressure system that was controlling the region's weather.

Light fog reported at the Valley surface during the early morning hours, resulted in slightly lower solar radiation intensities. Along with lower solar radiation intensities due to the low sun angle and reduced daylight hours, the atmospheric chemistry reactions may have favored the secondary particulate forming regime. Chemical composition and meteorological data showed limited mixing depths and light and disorganized wind flow resulting in minimal transport and dispersion of pollutants. Event # 5 came to an end when a significant trough from the eastern Pacific moved through the region on January 8th, bringing superior dispersion conditions and measurable amounts of precipitation.

Table 20 PM₁₀ Chemical Composition Data¹ for January 1, 4 and 7, 2001 at selected exceedance sites.

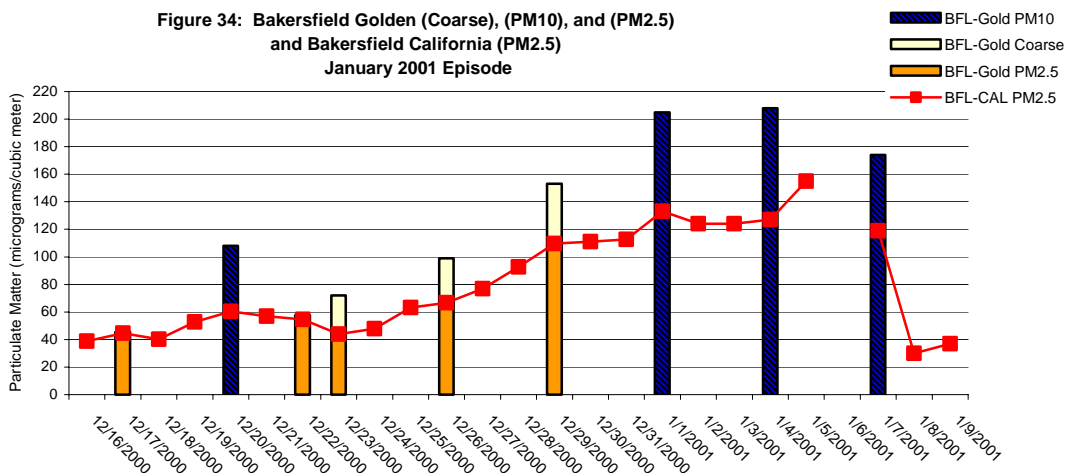
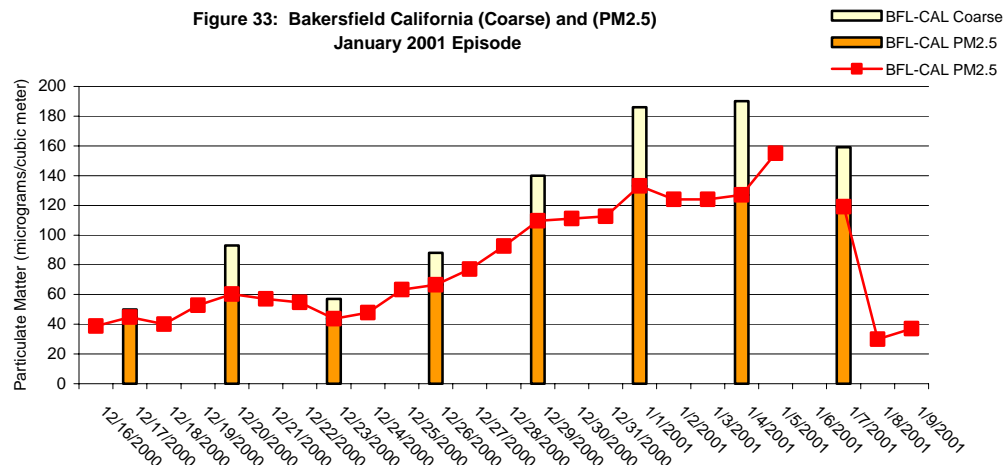
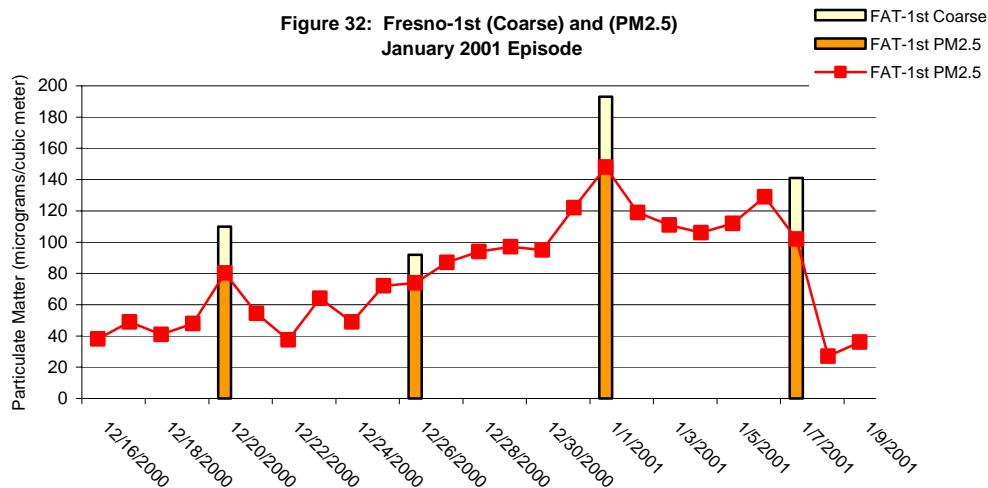
Data Collected as part of the Routine and CRPAQS Networks.

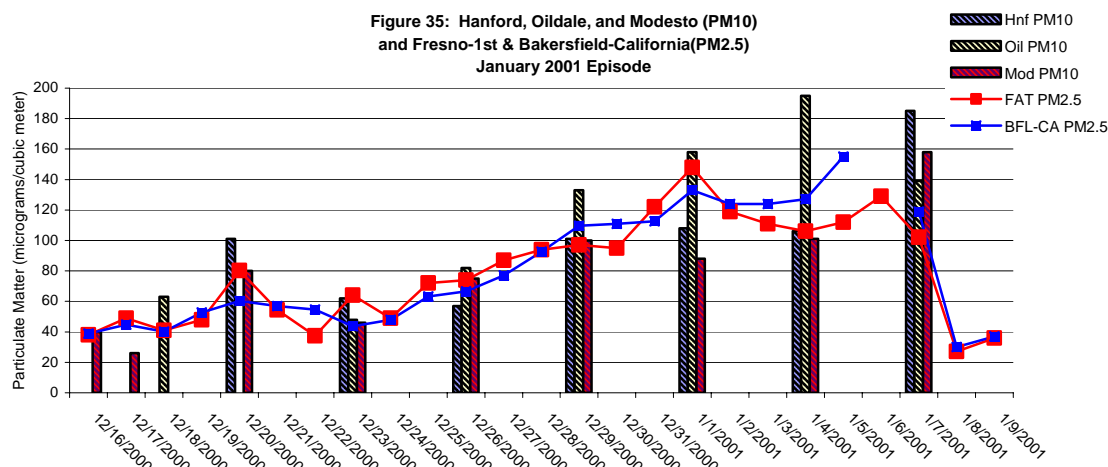
SITE NAME	Date	Concentrations (µg/m ³)					Percent of PM ₁₀ Mass			
		PM ₁₀	PM _{2.5}	Nitrate/ Sulfate	TC	Geo- logical	PM _{2.5}	Nitrate/ Sulfate	TC	Geo- logical
Bakersfield-California	1/1/01	186	133	100	33		71	54	18	
Bakersfield-California	1/4/01	190	127	98	30		67	51	16	
Bakersfield-California	1/7/01	159	119	81	24		75	51	15	
<i>Bakersfield-Golden</i>	1/1/01	205								
<i>Bakersfield-Golden</i>	1/4/01	208		106	38	47		51	18	23
<i>Bakersfield-Golden</i>	1/7/01	174								
Clovis-N. Villa	1/1/01	155	130	77			84	50		
Corcoran-Patterson	1/7/01	165	121	93			73	56		
Fresno-1st Street	1/1/01	193	148	76	51	7	77	40	26	4
<i>Fresno Drummond</i>	1/1/01	186								
<i>Fresno Drummond</i>	1/4/01	159		58	52	29		37	33	18
Hanford-S. Irwin	1/7/01	185		105				57		
Modesto-14 th St.	1/7/01	158	136	88	26		86	56	16	
Oildale-Manor	1/1/01	158	141	96			89	61		
<i>Oildale-Manor</i>	1/4/01	195		119	28	43		61	14	22

¹ The following fonts were used in the table to distinguish data sources:

- Regular font for routine data (FRM mass and chemical composition)
- Underlined font for mass collected using dichotomous sampler

Italics font for CRPAQS data





Event #6: January 12, 2001 through January 24, 2001

Meteorologically, dispersion worsened and particulate formation conditions became more favorable from January 14th to January 23rd. As is shown in **Figure 31**, event #6 lasted about 12 days and was marked by a gradual buildup of PM_{2.5} that lead to multiple days the Federal PM_{2.5} Standard was exceeded. After the passage of a trough on January 13th, which brought measurable precipitation across the region, moisture became available for atmospheric chemistry reactions. Humidity measurements of 90 – 100 % in the morning across the Valley Floor showed a moist atmosphere, with light fog and haze being reported on measured high PM_{2.5} days. These cool damp mornings and strong stability favored the formation of nitrates and sulfates.

Synoptically during event #6, the eastern Pacific high built over the Pacific Northwest on January 15th then expanded southward on the 18th, bringing increasing stability and poor dispersion conditions through January 22nd. During this period, the high strengthened and intensified on January 18th, further tightening the lid and trapping the pollutants within the San Joaquin Valley boundary layer.

With a strong lid in place aloft and maximum high temperatures in the low 50's on the 18th and 19th, and low 60's on the 20th through the 22nd, the afternoon hours were marked by limiting mixing, resulting in increasing particulate potential. Mixing heights at Fresno remained below 500 feet under a strong inversion during a majority of the day (20 or more hours) on days when the fine particulates climbed above the Standard. During the afternoon hours, there were high mixing depths (maximum mixing depth of 1,500 to 2,500 feet), but the bulk of the day had limited mixing. Maximum and minimum temperatures from January 18th through the 21st, were below normal, indicating a potential for increase residential wood burning emission activity, and nitrate forming reactions.

Light fog and haze were reported at the Valley surface during the early morning hours of January 18th through the 22nd, resulting in slightly lower solar radiation intensities. Along with lower solar radiation intensities due to the early morning fog and haze, low sun angle, and reduced daylight hours, the atmospheric chemistry reactions may have favored the secondary particulate forming regime. Light fog would be indicated of moderate water content's that contribute to the formation of ammonium nitrate.

Meteorological data showed during event #6 limited mixing depths and light and disorganized wind flow resulted in minimal transport and dispersion of pollutants. Both primary and secondary pollutants from local emissions across the San Joaquin Valley accumulated resulting in the exceedance of the 24-hour PM_{2.5} standard at Fresno-1st on January 16th through January 22nd, Visalia-Church, Corcoran-Patterson, Oildale-Manor, Bakersfield-Golden, Bakersfield-California, Angiola, and Edison, on January 19th, Modesto-14th, Angiola, and Bakersfield-Californian on January 20th, Angiola and Bakersfield-California on January 21st, Angiola, Bakersfield-California, Corcoran-Patterson, Visalia-Church, and Bakersfield-Golden on January 22nd. A vigorous cold front moved over the San Joaquin Valley on January 23rd, bringing an end to event # 6 that lasted from January 12th through January 24th. This disturbance brought superior dispersion conditions across the Valley, allowing pollutants to lower into the 5 to 11 micrograms per cubic meter range (background levels).

Event #7: January 25th through February 7th, 2003

A series of Pacific storms moved through the region from January 25th through January 30th, resulting in superior dispersion conditions over the San Joaquin Valley, with PM_{2.5} concentrations nearing background levels. As is evident in **Figure 31**, event #7 lasted about 13 days and was marked by a gradual buildup of PM_{2.5} that led to multiple days the Federal PM_{2.5} Standard was exceeded. High pressure rebuilt over the region on January 31st, leading to building particulate concentrations over the central and southern portions of the District. Meteorologically, dispersion rapidly deteriorated and particulate formation conditions became more favorable on February 1st. Humidity measurements of 90 – 100 % in the morning across the Valley Floor showed a continued moist atmosphere, with light fog and haze being reported on measured high PM_{2.5} days. These cool damp mornings and strong stability favored the formation of nitrates and sulfates.

Synoptically during event #7, the eastern Pacific high built along the West Coast on February 1st then expanded eastward on the 2nd, bringing strengthening stability and poor dispersion conditions through the end of event # 7 on February 6th. During this period, the high strengthened and intensified on February 1st, further tightening the lid trapping the pollutants within the San Joaquin Valley boundary layer.

With a strong lid in place aloft and maximum high temperatures in the mid to upper 60's, the afternoon hours were marked by limited mixing, resulting in increasing particulate potential. Mixing heights at Fresno remained below 500 feet under a strong inversion

during a majority of the day (18 or more hours) on days when the fine particulates climbed above the NAAQS. During the afternoon hours, there were high mixing depths (maximum mixing depth of 1,000 to 2,500 feet), but the bulk of the day had limited mixing. Maximum and minimum temperatures from February 3rd through the 5th were above normal. Light fog and haze were reported at the Valley surface during the early morning hours of February 3rd through the 5th, resulting in slightly lower solar radiation intensities.

Along with lower solar radiation intensities due to the early morning fog and haze, the atmospheric chemistry reactions may have favored the secondary particulate forming regime. Light fog would be indicated of moderate water content's that contribute to the formation of ammonium nitrate. Meteorological data showed limited mixing depths and light and disorganized wind flow resulted in minimal transport and dispersion of pollutants. An exceedance of the 24-hour PM_{2.5} standard were measured at Bakersfield California on February 3rd through the 5th, Bakersfield Golden on February 3rd and 6th, Corcoran on February 3rd, Fresno 1st on February 3rd and 4th, and Clovis on February 3rd. A cold front traversed over the San Joaquin Valley late in the afternoon on February 6th, producing trace amounts of precipitation across different parts of the District. This frontal passage brought weak to moderate dispersion conditions across the Valley, lowering PM_{2.5} levels to below the NAAQS. A vigorous upper level system moved through the region on the 7th, allowing for pollutants to lower to near background levels, bringing an end to event #7.

13.0 INTEGRATED ANALYSIS OF ATMOSPHERIC CHEMISTRY AND METEOROLOGY DURING THE JANUARY 2001 EPISODE

The January 2001 particulate episode was characterized by a prolonged period (three and a half weeks) of strong stability and light wind flow, which resulted in poor atmospheric dispersion conditions across the San Joaquin Valley. Coarse and fine particulates accumulated during the period leading to three separate days exceeding the National Ambient Air Quality Standards (NAAQS). These exceedances occurred on January 1, 4, and 7, 2001 and were measured by Federal Reference Monitoring (FRM) sites and MiniVol Samplers, which were part of the California Regional Particulate Air Quality Study (CRPAQS). The CRPAQS exceedances are not considered for compliance with the Federal Standards, but are used in the discussion to provide context to the episode. PM_{10} and $PM_{2.5}$ concentrations, chemical composition, and meteorological data around January 1, 4, and 7, 2001 were evaluated and analyzed to identify the characteristics and uniqueness of the exceedances at the FRM and CRPAQS PM_{10} monitoring sites.

PM_{10} and $PM_{2.5}$ Mass Concentrations

Daily $PM_{2.5}$ sampling and meteorological conditions suggest that PM_{10} exceedances began on December 31, 2000 and continued through January 7, 2001 at various monitoring sites across the San Joaquin Valley. $PM_{2.5}$ exceedances began a few days earlier on December 25 and 26, 2000, when real-time monitors captured readings above the Federal Standard of $65 \mu\text{g}/\text{m}^3$. Although PM_{10} sampling is not conducted daily, information from more frequent $PM_{2.5}$ sampling combined with an assessment of changes in the meteorological conditions suggest that the highest PM_{10} concentrations were not captured on the sampled days. The highest PM_{10} concentrations may have occurred on January 1st and January 6th, when Fresno 1st measured a peak $PM_{2.5}$ concentration of 148 and $129 \mu\text{g}/\text{m}^3$, respectively. PM_{10} samples were available on January 1st. However, no PM_{10} data was available on January 6th. Particulate material concentrations were dominated by fine particulates ($PM_{2.5}$) of ammonia nitrate and sulfate and were most prevalent across the entire San Joaquin Valley.

Although dispersion was poor, given the length of the episode and the large contributions from secondary components, there was an underlying regional component to this episode as it progressed through January 7th. Local carbon and geologic contributions added to this regional component and influenced site to site concentration variations. As the episode continued, PM and precursors became more homogeneous across the region. This resulted in $PM_{2.5}$ concentrations at rural sites lagging those of urban sites, and rural concentrations continued to build throughout the episode.

The FRM sites which exceeded the Federal PM_{10} standard on January 1, 2001, were Clovis-Villa $155 \mu\text{g}/\text{m}^3$, Fresno-1st $193 \mu\text{g}/\text{m}^3$, Fresno-Drummond $186 \mu\text{g}/\text{m}^3$, Bakersfield-California $186 \mu\text{g}/\text{m}^3$, Bakersfield-Golden $205 \mu\text{g}/\text{m}^3$, and Oildale-Manor $158 \mu\text{g}/\text{m}^3$ (**Figure 36, 37, 38, and 39 and Table 21**). PM_{10} at other Valley locations were elevated but not over the Standard. For example, Stockton-Wagner and Visalia-Church

recorded $119 \mu\text{g}/\text{m}^3$ and $143 \mu\text{g}/\text{m}^3$, respectively. The size fraction data on January 1st across the Valley indicated that most of the PM_{10} mass was in the $\text{PM}_{2.5}$ fraction, with an average $\text{PM}_{2.5}/\text{PM}_{10}$ mass ratio greater than 0.7. This was further supported by the high $\text{PM}_{2.5}$ concentrations that reached $148 \mu\text{g}/\text{m}^3$ at Fresno-First and $133 \mu\text{g}/\text{m}^3$ at Bakersfield-Golden (**Figure 36 and 38**).

Stagnation conditions continued through January 4, 2001, when three MiniVol Samplers, which were part of the California Regional Particulate Air Quality Study (CRPAQS) and one federal reference monitor (FRM) registered exceedances of the Federal Standard. The CRPAQS monitors measured at Fresno-Drummond, $159 \mu\text{g}/\text{m}^3$, at Bakersfield-Golden, $208 \mu\text{g}/\text{m}^3$, and at Oildale-Manor, $195 \mu\text{g}/\text{m}^3$ (**Figure 38 and 39 and Table 21**). The FRM PM_{10} concentration at Bakersfield-California was $190 \mu\text{g}/\text{m}^3$ (**Figure 37 and Table 21**). The size fraction data across the Valley on January 4th indicated that most of the PM_{10} was in the $\text{PM}_{2.5}$ fraction, with an average $\text{PM}_{2.5}/\text{PM}_{10}$ mass ratio greater than 0.8. This was further supported by the high $\text{PM}_{2.5}$ concentrations that reached $106 \mu\text{g}/\text{m}^3$ at Fresno-First and $127 \mu\text{g}/\text{m}^3$ at Bakersfield-California (**Figure 36, 38, & 39**).

Poor dispersion conditions continued through January 7, 2001, when five FRM monitors registered exceedances of the Federal Standard. The FRM sites, which exceeded the Federal PM_{10} Standard on January 7th, were Bakersfield-California, $159 \mu\text{g}/\text{m}^3$, Bakersfield-Golden, $174 \mu\text{g}/\text{m}^3$, Corcoran-Patterson, $165 \mu\text{g}/\text{m}^3$, Hanford-Irwin, $185 \mu\text{g}/\text{m}^3$, and Modesto-14th, $158 \mu\text{g}/\text{m}^3$ (**Figure 37, 38, and 39 and Table 21**). The size fraction data across the Valley on January 7, 2001 indicated that most of the PM_{10} was in the $\text{PM}_{2.5}$ fraction, with an average $\text{PM}_{2.5}/\text{PM}_{10}$ mass ratio greater than 0.75. This was further supported by the high $\text{PM}_{2.5}$ concentrations that reached $101 \mu\text{g}/\text{m}^3$ at Fresno-First and $119 \mu\text{g}/\text{m}^3$ at Bakersfield-California (**Figure 36 & 37**). Chemical composition data was then analyzed to identify the characteristics and uniqueness of the exceedances at the FRM and CRPAQS PM_{10} monitoring sites.

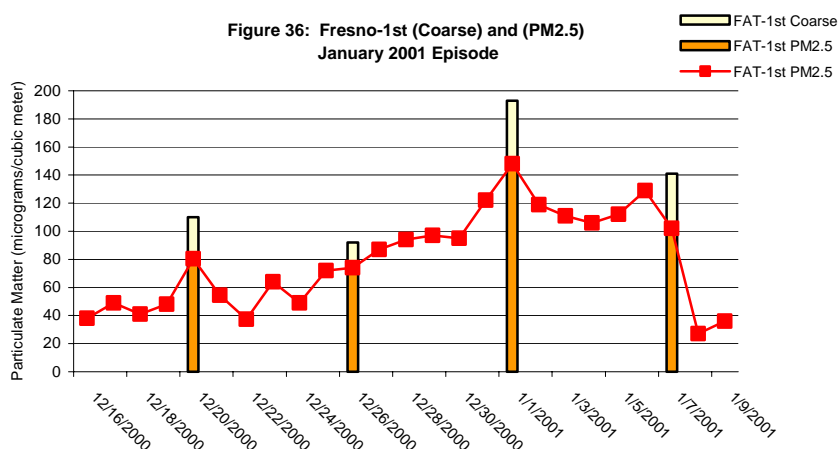


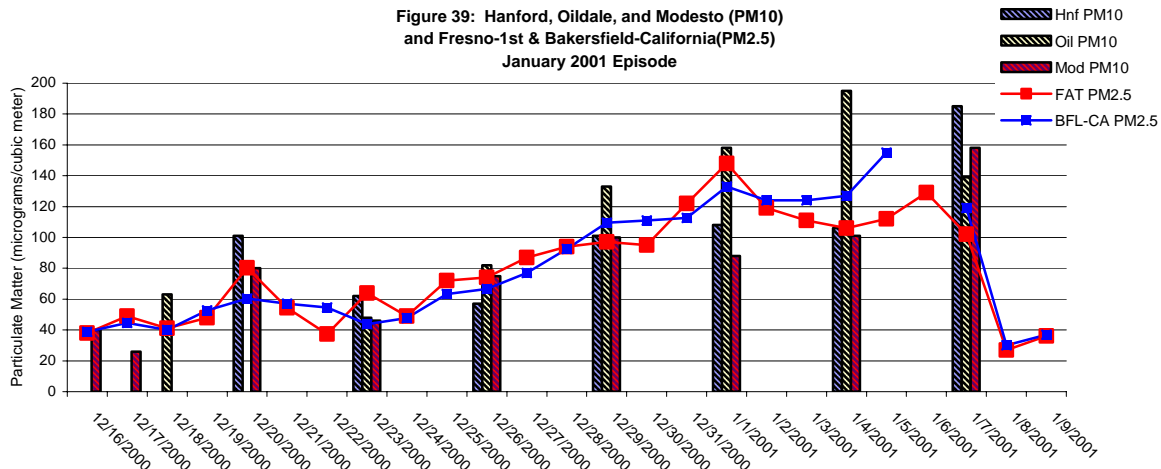
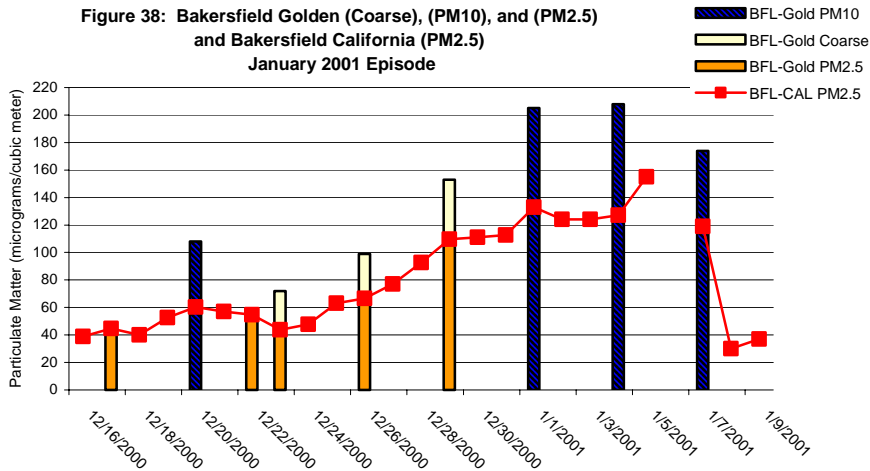
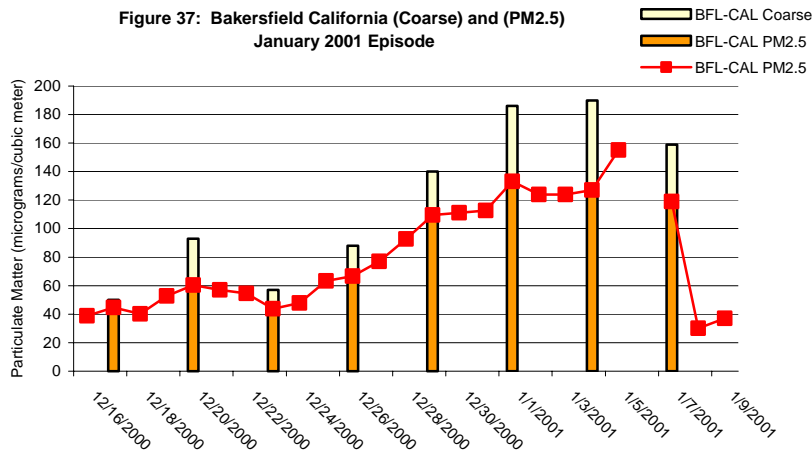
Table 21 PM₁₀ Chemical Composition Data¹ for January 1, 4 and 7, 2001 at selected exceedance sites.

Data collected as part of the Routine and CRPAQS Networks.

SITE NAME	Date	Concentrations (µg/m ³)					Percent of PM ₁₀ Mass			
		PM ₁₀	PM _{2.5}	Nitrate/ Sulfate	TC	Geo- logical	PM _{2.5}	Nitrate/ Sulfate	TC	Geo- logical
Bakersfield-California	1/1/01	186	133	100	33		71	54	18	
Bakersfield-California	1/4/01	190	127	98	30		67	51	16	
Bakersfield-California	1/7/01	159	119	81	24		75	51	15	
<i>Bakersfield-Golden</i>	1/1/01	205								
<i>Bakersfield-Golden</i>	1/4/01	208		106	38	47		51	18	23
<i>Bakersfield-Golden</i>	1/7/01	174								
Clovis-N Villa	1/1/01	155	130	77			84	50		
Corcoran-Patterson	1/7/01	165	121	93			73	56		
Fresno-1st Street	1/1/01	193	148	76	51	7	77	40	26	4
<i>Fresno Drummond</i>	1/1/01	186								
<i>Fresno Drummond</i>	1/4/01	159		58	52	29		37	33	18
Hanford-S Irwin	1/7/01	185		105				57		
Modesto-14th St.	1/7/01	158	136	88	26		86	56	16	
Oildale-Manor	1/1/01	158	141	96			89	61		
<i>Oildale-Manor</i>	1/4/01	195		119	28	43		61	14	22

¹ The following fonts were used in the table to distinguish data sources:

- Regular font for routine data (FRM mass and chemical composition)
- Underlined font for mass collected using dichotomous sampler
- Italics font for CRPAQS data



Chemical Composition Data

Ammonium nitrate and sulfates increased prior to the exceedance day on January 1, 2001, whereas total carbon and geological remained stable. Chemical composition

data on January 1, 2001 showed the exceedances were driven by high concentrations of ammonium nitrate and sulfate that comprised of 40 to 60 % of the PM₁₀ mass. The other major chemical components of the samples were 18 to 26 % total carbon and 4 to 20 % geological of the PM₁₀ mass (**Table 21**). At Fresno-First the concentration of total carbon (26 % of PM₁₀ mass) and coarse material (4 % of PM₁₀ mass) indicated the constituents of the particulate samples on January 1st may predominantly come from local sources, such as residential wood burning (**Table 21**). Since December 2000 No Burn Day's were declared District-wide; consequently, agricultural burning was probably not a contributing source of PM on the exceedance days in January. However, burn variances and noncompliant agricultural burns may have contributed to a small portion of the samples. Overnight minimum temperatures in the low 30's on January 1, 4 and 7, 2001 suggested that residential wood burning may have been a significant source of PM₁₀. The potential of increased residential wood burning on New Year's Day, may have led to elevated concentrations of total carbon in the samples.

Local emission source activity and meteorological conditions led to PM₁₀ concentrations at Bakersfield-Golden, Oildale-Manor, and Bakersfield-California climbing between January 1st and the 4th. Fresno-Drummond PM₁₀ concentrations lowered during this same period. Because limited mixing and light winds remained over the area, this decrease in PM₁₀ at the site may have been due to lower emission activity there. Analysis of ammonium nitrates and sulfates indicates that Oildale-Manor and Bakersfield-California registered higher levels compared to non-exceedance locations, indicating potentially that local emissions sources may have impacted these sites. The exceedances at Fresno-Drummond, Oildale-Manor, and Bakersfield-California and Golden on January 4th, were driven by high concentrations of ammonia nitrate and sulfate and/or total carbon.

The concentration at Bakersfield-Golden of ammonium nitrate and sulfate (106 µg/m³), total carbon (18 µg/m³), and geological (23 µg/m³), was the highest PM₁₀ mass in the Valley on January 4th (**Table 21**). The concentration at Oildale-Manor, Bakersfield-California, Fresno-Drummond, were the second, third and fourth highest PM₁₀ mass in the Valley (**Table 21**). The constituents of the particulate samples on January 4, 2001 may predominantly come from local sources (residential wood burning and urban / agricultural geologic). The lack of precipitation since December 9th may have also contributed to the increasing geological component. PM₁₀ and PM_{2.5} concentrations showed that meteorological conditions led to the pollution buildup. Ammonium nitrate and sulfates, and geological increased prior to the exceedance on January 4, 2001, whereas total carbon remained stable.

Local emission source activity and meteorology led to PM₁₀ concentrations at Hanford-Irwin, Corcoran-Patterson, and Modesto-14th climbing between January 4th and the 7th, while PM₁₀ concentrations at Bakersfield-Golden and California lowered. Because dispersion conditions remained poor, local emission activity around Bakersfield may have decreased prior to January 7th leading to lowering PM₁₀ levels. Both Bakersfield California and Golden measured lower ammonium nitrate and sulfate levels compared to the 4th, further indicating that potentially local emission source activity may have

decreased on the 7th at these sites. Analysis of ammonium nitrates and sulfates indicates that Modesto-14th, Hanford-Irwin, Corcoran-Patterson, registered higher levels compared to non-exceedance locations, indicating potentially that local emissions sources may have impacted these sites.

The exceedances at Bakersfield-California, Bakersfield-Golden, Corcoran-Patterson, Hanford-Irwin, and Modesto-14th were driven by high concentrations of ammonia nitrate and sulfate and/or total carbon, which remained high and elevated between January 4th and January 7th. Ammonium nitrate and sulfates, and total carbon increased prior to the exceedance on January 7, 2001 at Modesto-14th, Corcoran-Patterson, and Hanford-Irwin whereas at Bakersfield-Golden and California ammonium nitrate and sulfates, and total carbon slightly decreased. The concentration at Hanford-Irwin of ammonium nitrate and sulfate ($105 \mu\text{g}/\text{m}^3$) and no total carbon and geological measurements, had the highest PM₁₀ mass in the Valley on January 7th (**Table 21**). The concentration at Bakersfield-Golden, Corcoran-Patterson, Bakersfield-California, Modesto-14th, had the second, third, fourth, and fifth highest PM₁₀ mass in the Valley (**Table 21**). The constituents of the particulate samples on January 7, 2001 may predominantly come from local emission sources (residential wood burning and urban / agricultural geologic).

Dispersion Meteorology

During the January 2001 episode, strong high pressure at the surface and aloft resulted in limited afternoon mixing and light offshore wind flow. Cool damp mornings and strong stability contributed to the formation of nitrates and sulfates during the episode. Meteorologically, dispersion worsened and particulate formation conditions strengthened from December 10th to January 7th. After the passage of a weak cold front on December 9, 2000, which brought a few hundredths of an inch of precipitation to the region, moisture became available for atmospheric chemistry reactions. Humidity measurements of 90 – 100 % in the morning across the Valley Floor showed a moist atmosphere, with light fog and haze being reported on the exceedance days. These cool damp mornings and strong stability favored the formation of nitrates and sulfates. Synoptically, the eastern Pacific high built over the San Joaquin Valley on December 10, 2000 and dominated the region's weather through January 7, 2001. The high strengthened and intensified a few days prior to January 1st, further tightening the lid and trapping pollutants within the San Joaquin Valley boundary layer.

With a strong lid in place aloft and maximum high temperatures in the upper 50's to low 60's, the afternoon hours were marked by limited mixing, resulting in increasing particulate potential. Mixing heights at Fresno remained below 500 feet under a strong inversion for 19 hours on January 1st, breaking out after 4:00 P.M and reforming shortly after 7:00 P.M. During the afternoon hours, there were higher mixing depths (maximum mixing depth of 1,000 feet), but the bulk of the day had limited mixing. Maximum and minimum temperatures for the exceedance day were slightly above normal, further illustrating the intensity of the high pressure system that was controlling the region's weather. Light fog was reported at the Valley surface during the early morning hours of January 1st, resulting in slightly lower solar radiation intensities. Along with lower solar

radiation intensities due to the early morning fog, low sun angle, and reduced daylight hours, the atmospheric chemistry reactions may have favored the secondary particulate forming regime. Light fog would be indicative of moderate water content's that favor the formation of ammonium nitrate. Heavier fogs result in the removal of particulates by wet deposition. Chemical composition and meteorological data showed limited mixing depths and light and disorganized wind flow resulted in minimal transport and dispersion of pollutants. Both primary and secondary pollutants from local emissions around Clovis-Villa, Fresno-1st, Fresno-Drummond, Bakersfield-California, Bakersfield-Golden, and Oildale-Manor accumulated resulting in the exceedance of the 24-hour PM₁₀ standard on January 1, 2001.

Meteorological conditions remained extremely stable between January 1st through the 4th, leading to elevated particulate conditions continuing across the San Joaquin Valley. Without a significant weather disturbance moving through the area to scour out the particulates, PM₁₀ concentrations continued to climb and exceeded the NAAQS at both the FRM and CRPAQS PM₁₀ monitoring sites on the second measured exceedance day on January 4th. With a strong lid in place aloft and maximum high temperatures in the low 60's, the afternoon hours on January 4th, were marked by limited mixing, resulting in increasing particulate conditions. Mixing heights at Fresno remained below 500 feet under a strong inversion for 20 hours on January 4th. During the afternoon hours, there were higher mixing depths (maximum mixing depth of 2,000 feet), but the bulk of the day had limited mixing. Maximum temperatures for this exceedance day were above normal, further illustrating the intensity of the high pressure system that was controlling the region's weather. Light fog reported at the Valley surface during the early morning hours, resulted in slightly lower solar radiation intensities. Along with lower solar radiation intensities due to the low sun angle and reduced daylight hours, the atmospheric chemistry reactions may have favored the secondary particulate forming regime. Chemical composition and meteorological data showed limited mixing depths and light and disorganized wind flow resulted in minimal transport and dispersion of pollutants. Both primary and secondary pollutants from local emissions around Fresno-Drummond, Bakersfield-Golden, Oildale-Manor, and Bakersfield-California accumulated resulting in the exceedance of the 24-hour PM₁₀ standard on January 4, 2001. The January 4th exceedances recorded the highest PM₁₀ levels during the January 2001 episode.

Between January 4th and January 7th, meteorological conditions began to slowly improve leading to slightly lower but continued elevated particulate conditions across the San Joaquin Valley. Without a significant weather disturbance moving through the area to scour out the particulates, PM₁₀ concentrations continued to remain high and exceeded the Federal Standard at five FRM PM₁₀ monitoring sites on the third measured exceedance day on January 7th. The FRM PM₁₀ concentrations at Bakersfield-California (159 µg/m³), Bakersfield-Golden (174 µg/m³), Corcoran-Patterson (165 µg/m³), Hanford-Irwin (185 µg/m³), and Modesto-14th (158 µg/m³) were captured on January 7th (**Figure 37, 38, and 39**). Humidity measurements of 85 – 100 % on the morning of January 7th, across the Valley Floor showed a relatively moist atmosphere, with light fog and haze being reported. The cool damp mornings and strong stability

avored the formation of nitrates and sulfates. Synoptically, the eastern Pacific high began to slowly weaken and move into the Intermountain Region on January 7, 2001, slightly weakening the lid over the San Joaquin Valley.

On January 7th a moderately strong lid was in place aloft and maximum high temperatures were in the mid 60's. The afternoon hours were marked by limited mixing, resulting in elevated particulate conditions. Mixing heights at Fresno remained below 500 feet under a strong inversion for 16 hours on January 7th. During the afternoon hours, there were higher mixing depths (maximum mixing depth of 2,000 feet), but the bulk of the day had limited mixing. Maximum temperatures for this exceedance day were above normal, further illustrating the intensity of the high pressure system that was controlling the region's weather. Light fog reported at the Valley surface during the early morning hours, resulted in slightly lower solar radiation intensities. Along with lower solar radiation intensities due to the low sun angle and reduced daylight hours, the atmospheric chemistry reactions may have favored the secondary particulate forming regime. Chemical composition and meteorological data showed limited mixing depths and light and disorganized wind flow resulting in minimal transport and dispersion of pollutants. Both primary and secondary pollutants from local emissions around Bakersfield-California and Golden, Corcoran-Patterson, Hanford-Irwin, and Modesto-14th, accumulated resulting in the exceedance of the 24-hour PM₁₀ standard on January 7, 2001.

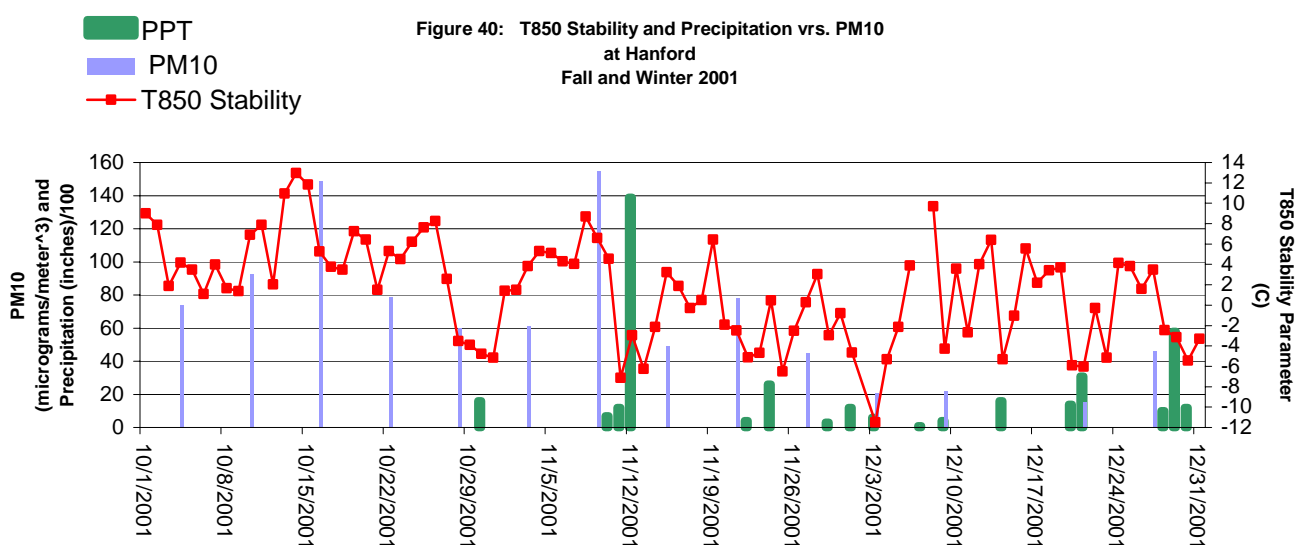
Conclusion

The 2001 episode was marked by a prolonged period of very strong stability and limited mixing, resulting in widespread exceedances of the Federal PM₁₀ Standard across the San Joaquin Valley. Although dispersion was poor, given the length of the episode and the large contributions from secondary components, there was an underlying regional component to this episode as it progressed through January 7th. Local carbon and geologic contributions added to this regional component and influenced site to site concentration variations. As the episode continued, PM and precursors became more homogeneous across the region. This resulted in PM_{2.5} concentrations at rural sites lagging those of urban sites, and rural concentrations continued to increase throughout the episode. Historically, the strength of the stability and length of the episode has not occurred often. The January 2001 exceedances were unique in that the meteorology was so strong and lasted for so long, that PM remained trapped and accumulated in the San Joaquin Valley, leading to widespread exceedances of the Federal PM₁₀ Standard by the end of the episode.

14.0 NOVEMBER 9, 2001 EPISODE SYNOPTIC METEOROLOGICAL DISCUSSION

October 31, 2001- November 10, 2001

The period from October 31 through November 10, 2001 was marked by 11 days of strong stability and poor atmospheric dispersion conditions. Strong high pressure both at the surface and aloft over the Intermountain Region dominated the period, leading to light and disorganized wind flow and limited dispersion. The period began with the passage of a vigorous cold front and upper level trough on the 31st, **Figure 40**. Between the 31st and the 10th, strong stability, light and disorganized wind flow, and poor dispersion conditions resulted in a PM₁₀ exceedance at Hanford on November 9th.



At Hanford, a 24-hour PM₁₀ (Particulate Matter) concentration of 155 $\mu\text{g}/\text{m}^3$ was measured. **Table 22** outlines federal reference method (FRM) Daily Average Particulate Matter measurements for sites across the San Joaquin Valley (SJV). In order to understand the variability of these measurements, an in depth examination of the synoptic pattern and surface winds and observations, and aircraft soundings leading to the episode were analyzed.

TABLE 22: Federal Reference Method (FRM) Daily Average Particulate Matter measurements for sites across the SJV for November 9, 2001.

	FRM			FRM			FRM	
Site Name	24-Avg.		Site Name	24-Avg.		Site Name	24-Avg.	
	10	2.5		10	2.5		10	2.5
Bakersfield-Gold	102		Modesto	115	69	Corcoran*	117	46
Bakersfield-CA		38	Merced-M St.	69	34	Stockton**	97	55
Visalia	74	38	Clovis	68	32	Fresno-1st	70	46
Hanford	155		Fresno-Drum	97		Turlock	124	

*-Patterson **- Hazleton

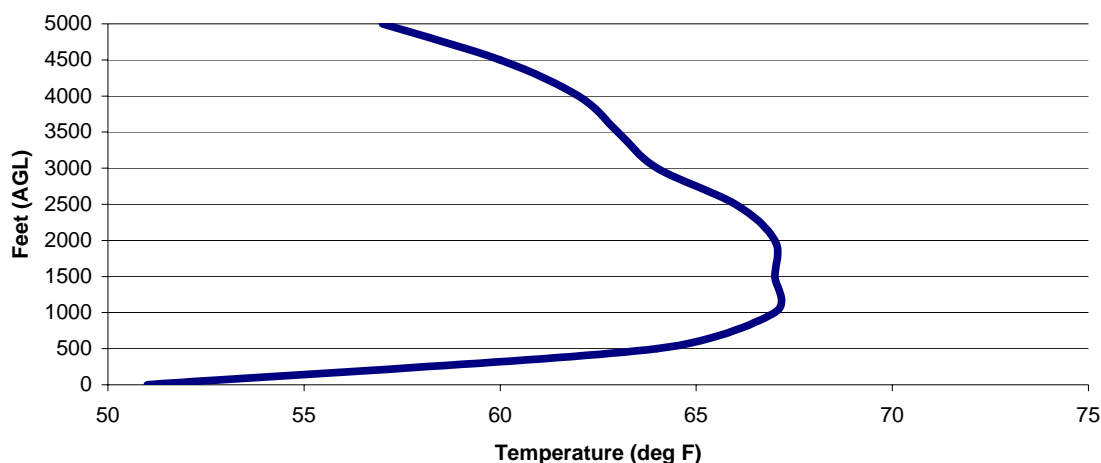
units in $\mu\text{g}/\text{m}^3$

The meteorological synoptic analysis showed a period of moderately strong atmospheric stability from October 31st through the November 10th. Ahead of a developing trough over the eastern Pacific, a strong mid and upper level ridge developed over the region on the 9th. This ridge strengthened the inversion over the San Joaquin Valley trapping particulates within the Valley boundary layer. The morning surface charts of the 9th depicted a strong surface high over the Intermountain Region, with a surface ridge extending southwestward across central California. The 12Z (4 a.m.) surface pressure gradient was -4.1 millibars from San Francisco (SFO) to Las Vegas (LAS), with isobars (constant surface pressure) orientated southeast to northwest. The alignment of the isobars and the -4.1 (SFO-LAS) millibars pressure gradient, represents light southeasterly wind flow across the San Joaquin Valley. Visibilities throughout the day across the San Joaquin Valley were reporting haze.

The morning temperature aircraft sounding over Fresno on the 9th showed a strong inversion (stable layer) of 16 degrees Fahrenheit from the surface up to 1,000 feet, turning isothermal (constant temperature) up through 2,500 feet as is evident in **Figure 41**. The morning temperature sounding over Bakersfield showed a very strong inversion of 22 degrees Fahrenheit from the surface up to 1,500 feet. The temperature sounding on the 9th, is conducive of elevated PM levels due to low mixing depths and very strong surface based inversions, which keep pollutants trapped near the surface. During the early morning surface observations across the San Joaquin Valley were cold. The minimum temperature recorded at Fresno was 49 degrees Fahrenheit. The minimum temperatures recorded at Bakersfield and Hanford were 45 degrees Fahrenheit. The maximum high temperatures recorded at Fresno and Hanford were 80 degrees Fahrenheit. The maximum high temperature recorded in Bakersfield was 83 degrees Fahrenheit. Fresno hourly temperature data shows very limited mixing conditions below 1,000 feet for over 18 hours of the day, increasing with afternoon

heating to a maximum mixing depth of 2,000 feet on the 9th.

Figure 41: Atmospheric Temperature Profile at Fresno on November 9, 2001



Upper level charts indicated a strong high over the Intermountain Region, with a ridge extending westward across central California. An upper level trough 750 NM west of San Francisco developed and moved closer to the Californian coastline on the 9th. Weak pressure gradients over the region remained rather flat through the day, leading to light southeasterly wind flow across the San Joaquin Valley.

Table 23 shows the 24 hour daily average wind speeds at SJVAPCD monitoring, ASOS, and CIMIS sites for November 09, 2001.

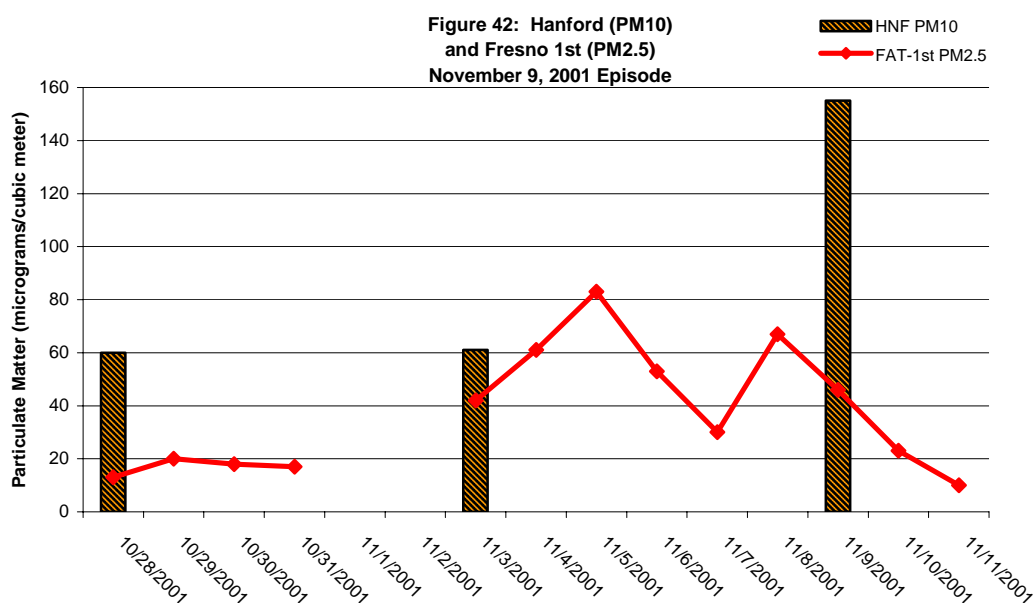
SJVAPCD Monitoring Sites		ASOS		CIMIS			
	WS		WS		WS		WS
	MPH		MPH		MPH		MPH
Clovis	2.4	Fresno	1.5	Shafter/USDA	3.0	Famoso	2.3
Fresno SSP	2.2	Bakersfield	5.3	Firebaugh/Telles	2.3	Westlands	4.1
Corcoran	2.3	Hanford	1.2	Stratford	1.8	Panoche	2.4
Edison	3.6	Madera	3.9	Kettleman	2.8	Arvin-Edison	3.0
Parlier	2.9	Merced	3.6	Visalia/Americas	2.1	Lindcove	2.1
Arvin	2.5			Parlier	1.2	Kesterson	2.4
Visalia	1.4			Blackwells Corner	3.5	Lodi West	1.3
				Los Banos	2.5	Modesto	3.4
				Manteca	2.8	Fresno State	2.3

Due to the strong stability lasting for over 10 days, PM₁₀ steadily increase region-wide until the sampling day on November 9th. With the mid and upper level stability aloft, surface based inversion, and light southeasterly wind flow, this weather pattern was conducive of elevated PM₁₀ measurements. As is evident in the PM data, local emissions contributed to the exceedance of the National Ambient Air Quality Standards (NAAQS) at Hanford on the 9th. The preceding day (the 8th) had higher atmospheric stability compared to the 9th, thus PM measurements would have been higher Valley

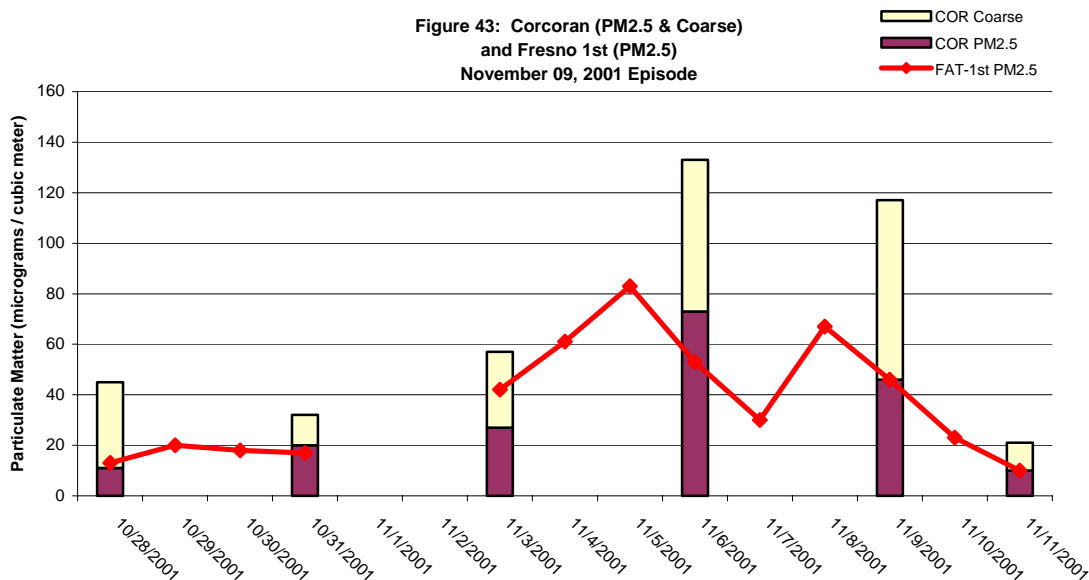
wide. Due to decreasing stability and increasing dispersion conditions into the 10th, PM gradually lowered with the approach of the trough from the eastern Pacific. Widespread showers developed across the region on the 10th, bringing an end to the November 9th PM event.

15.0 INTEGRATED ANALYSIS OF ATMOSPHERIC CHEMISTRY AND METEOROLOGY DURING THE NOVEMBER 9, 2001 EPISODE

The November 9, 2001 particulate episode was characterized by a medium length period (a week and a half) of strong stability and light wind flow, which resulted in poor atmospheric dispersion conditions across the San Joaquin Valley. Coarse and fine particulates accumulated during the period, leading to an exceedance of the 24-hour standard at one air monitoring site on November 9, 2001. Concentrations were dominated by the coarse particulates (PM_{10}) and were most prevalent across Kern County early in the episode then progressively spread northward to Stanislaus and San Joaquin Counties toward the end of the episode. The highest PM_{10} measured was $155 \mu\text{g}/\text{m}^3$ (**Figure 42**) at Hanford-S Irwin. PM_{10} at other Valley locations were lower between 115 to $125 \mu\text{g}/\text{m}^3$ (**Figure 43**). During the period, strong high pressure at the surface and aloft resulted in limited afternoon mixing and light offshore wind flow. Cool damp mornings and strong stability contributed to the formation of nitrates and sulfates during the episode. These meteorological conditions led to elevated particulate concentrations. Chemical composition and meteorological data around November 9, 2001, was evaluated and analyzed to identify the characteristics and uniqueness of the exceedance at Hanford-S Irwin.



Although PM_{10} sampling is not conducted daily, information from more frequent $PM_{2.5}$ sampling combined with an assessment of changes in the meteorological conditions suggest that the highest PM_{10} concentration was not captured on the sampled day. Daily $PM_{2.5}$ sampling and meteorological conditions suggested that the highest PM_{10} concentrations may have occurred on November 8th, when Fresno 1st measured a peak $PM_{2.5}$ concentration of $67 \mu\text{g}/\text{m}^3$. No chemical composition data was available for the exceedance day. However, the size fraction data across the Valley indicated that most of the PM_{10} was in the coarse fraction, with an average $PM_{2.5}/PM_{10}$ ratio of slightly greater than 0.40 at nearby Corcoran (**Figure 43**).



The concentration of coarse material may have been highest at the exceedance site as indicated by the higher coarse fraction at nearby Corcoran compared to other sites in the Valley. In November, many agricultural land preparing and harvesting activities were occurring, potentially contributing to the elevated concentrations of geological material found in the sample. Agricultural burning probably did not contribute to PM on the exceedance day, because November 8 and 9, 2001 were declared No Burn Day's District-wide. However, burn variances and noncompliant agricultural burns may have contributed to a small portion of the samples. Overnight minimum temperatures in the mid to upper 40's suggest that residential wood burning may have been a source of PM₁₀. The PM_{2.5} temporal patterns across the Valley showed highest concentrations in Bakersfield on November 3 and 4 followed by peak concentrations on November 5 at Fresno, then the following day on November 6 at Corcoran. A few days later on November 9, the exceedance day at Hanford, peak PM_{2.5} concentrations were recorded in the northern portions of the Valley (Modesto and Stockton). As discussed below, both PM₁₀ and PM_{2.5} concentrations showed that meteorological conditions led to the temporal variability and pollution buildup.

Meteorologically, dispersion worsened and particulate formation conditions strengthened from November 2nd to the 7th. However, on November 8th the day before the exceedance day at Hanford, dispersion conditions began to slightly improve under weaker stability. After the passage of a cold front on October 30th, which brought 0.16 inches of rainfall to Hanford, moisture was available for atmospheric chemistry reactions. Humidity measurements of 80 – 95% in the morning across the Valley Floor showed a moist atmosphere, with light fog and haze being reported. The cool damp mornings and strong stability favored some formation of nitrate and sulfate particulates. The eastern Pacific high built over the San Joaquin Valley on November 2nd, and dominated the region's weather through the 10th. The high began to slowly break down on the 8th, but remained strong through the exceedance day (November 9th), trapping pollutants within the San Joaquin Valley boundary layer.

With a strong lid in place and maximum high temperatures in the upper 70's to low 80's on November 9, the afternoon hours were marked by limited mixing, resulting in elevated particulate conditions. Mixing heights at Fresno remained below 500 feet under a strong inversion for 16 hours on November 9, 2001 breaking out by 10:00 A.M. and reforming by 5:00 P.M. During the afternoon hours, there were higher mixing depths (maximum mixing depth of 2,000 feet), but the bulk of the day had limited mixing. Maximum temperatures were above normal for the November 2001 episode, further illustrating the intensity of the high pressure system that was controlling the region's weather. Light fog being reported at the Valley surface on November 9th, resulted in slightly lower levels of solar radiation intensity. Along with lower solar radiation intensities due to the low sun angle and decreasing daylight hours, atmospheric chemistry reactions may have favored the secondary particulate forming regime.

Chemical composition and meteorological data showed that limited mixing depths and light and disorganized wind flow resulted in minimal transport and dispersion of pollutants. Due to the seasonality of the November 9th exceedance, the PM₁₀ concentration at Hanford had a dominant coarse fraction compared to exceedances, which occur later in the winter. The duration, moisture availability, light winds, and maximum and minimum temperatures influenced the atmospheric chemistry reactions, during the episode. This led to higher coarse fractions and geological components compared to episodes later in the year. With stagnant weather conditions, local geological sources around Hanford led to the exceedance. Both primary and secondary pollutants from local emissions around Hanford-S Irwin accumulated, resulting in the exceedance of the 24-hour PM₁₀ standard on November 9, 2001.

16.0 MAY 19 AND 20, 2002 EPISODE SYNOPTIC METEOROLOGICAL DISCUSSION

May 19, 2002

A wind blown dust event occurred across parts of the central and southern San Joaquin Valley on May 19, 2002. At McFarland, a 24-hour PM₁₀ (Particulate Matter) concentration of 407 µg/m³ was measured. The McFarland measurement was taken 8AM to 8AM daily, whereas all other sites are measured midnight to midnight daily. **Table 24** outlines the Peak and Daily Average Particulate Matter Measurements at McFarland, Corcoran, Clovis, and Fresno-1st. In order to understand the variability of these measurements, an in depth examination of the synoptic pattern and surface winds and observations, aircraft soundings, pibal (balloon) wind measurement, and lower air profiler measurements leading to the episode were analyzed.

TABLE 24: Peak and Daily Average Particulate Matter Measurements for sites across the SJV for May 19, 2002

	PM ₁₀ -Teom		PM ₁₀ -BAM		PM _{2.5} -BAM	
Site Name	Peak	24-Avg.	Peak	24-Avg.	Peak	24-Avg.
McFarland	*	407 [#]	*	*	*	*
Corcoran	235	39	674	84	27	13
Clovis	106	29	*	*	*	*
Fresno-1 st	*	*	*	*	8	4

*-N/A

units in µg/m³

The meteorological synoptic analysis showed that an unseasonably, deep trough developed across the eastern Pacific, the morning of the 19th. The trough slowly pushed southeastward across California during the afternoon hours. The morning surface charts depicted a surface high pressure ridge draped across central California to Reno, with a thermal low near Las Vegas. The 12Z surface pressure gradient was +9.4 millibars from San Francisco (SFO) to Las Vegas (LAS). A +9.4 millibars pressure gradient means onshore or down-valley flow, which results in strong northwesterly winds across the San Joaquin Valley. A developing cold front curved southward into the eastern Pacific from a moderate low 600 NM west of Eureka.

The morning temperature soundings over Fresno showed an isothermal (slightly stable) layer up to 4,000 feet. At Bakersfield the temperature sounding showed a similar isothermal layer up to 3,000 feet. The morning pibal wind measurement from Fresno, depicted strong northwesterly flow decoupled from the surface at 37 knots at 1,000 feet continuing northwesterly up to 4,000 feet, then shifting westerly up to 5,000 feet, and then backing southerly above 5,000 feet.

Upper level charts indicated a strong low 750 NM west of Eureka, with a trough digging southward across the eastern Pacific. A strong temperature gradient (packing) at 850 MB and an intense upper level (300 MB) jet were evident across northwestern California on the 12Z analysis maps. The strong temperature gradient aloft, along with an intense upper level jet, manifested the surface pressure gradient, resulting in strong to gusty winds measured at several hourly-surface meteorological monitoring sites and aloft at the Visalia and Lost Hills lower air profiler sites. **Table 25** shows the 24 hour daily average wind speeds at SJVAPCD air monitoring, ASOS, and CIMIS sites for May 19, 2002.

Table 25: 24 hour average wind speeds at SJVAPCD air monitoring, ASOS, and CIMIS sites for May 19, 2002.

SJVAPCD Air Monitor		ASOS		CIMIS			
	WS		WS		WS		WS
	MPH		MPH		MPH		MPH
BFLD-Gold	6.8	BFLD Meadows	11.6	FivePoints	11.2	Famoso	5.2
Clovis	7.5	Fresno YI	9.4	Shafter/USDA	6.3	Orange Cove	5.5
Fresno SSP	4.4	Hanford	9	Firebaugh/Telles	5.9	Madera	7.2
Madera Pump	7.5	Madera-AP	10.2	Stratford	7.5	Belridge	6.8
Maricopa	9.2	Merced-AP	8.7	Kettleman	5.2	Merced	4.4
Merced-Coffee	6.2	Modesto-AP	6.7	Visalia/Americas	5.1	Patterson	6.8
Parlier	8.4	Stockton-AP	6.6	Parlier	6.6	Lodi West	2.2
Tracy	9.0			Blackwells Corner	14	Tracy	7.3
Turlock	4.8			Los Banos	8.6	Porterville	4.9
Visalia LAP	6.8			Manteca	4.6	Lost Hills	9.1
				Modesto	6.4	Delano	6.1
				Fresno State	6.7	Westlands	8.1
				Lindcove	3.9	Panoche	6.8
				Kesterson	6.1	Arvin-Edison	6.1

Lower air profiler data from Visalia and Lost Hills showed that with solar insulation (heating) the stable isothermal layer present in the morning began to mix out by 11-12 PDT (18Z-19Z), resulting in strong winds aloft mixing to the surface (**Figure 44 and 45**). The ASOS hourly observations showed northwesterly flow across the San Joaquin Valley (down-valley). At Bakersfield, Hanford, and Lemoore, winds were light and variable in the morning. As the strong temperature gradient aloft and upper level jet began to nose into the region, combined with the strong surface gradient and afternoon heating, gusty northwesterly winds developed across the southern San Joaquin Valley during the afternoon; with Hanford ASOS reporting winds at 10.4 mph gusting to 20 mph and Lemoore with winds at 12.7 mph gusting to 23 mph at the 13:55 PDT observation. Reduced visibilities of 5 miles were later noted at Hanford around 16:53 PDT when winds were at 17.3 mph gusting to 26.5 mph. Gusty winds continued into the early evening hours and began diminishing after 21:00 PDT. TEOM and BAM hourly measurements, at Corcoran immediately showed the diminishing wind speeds, by measurements lowering to 20 $\mu\text{g}/\text{m}^3$.

Figure 44: Visalia Lower Air Profiler image for May 19-May 20th, 2002.

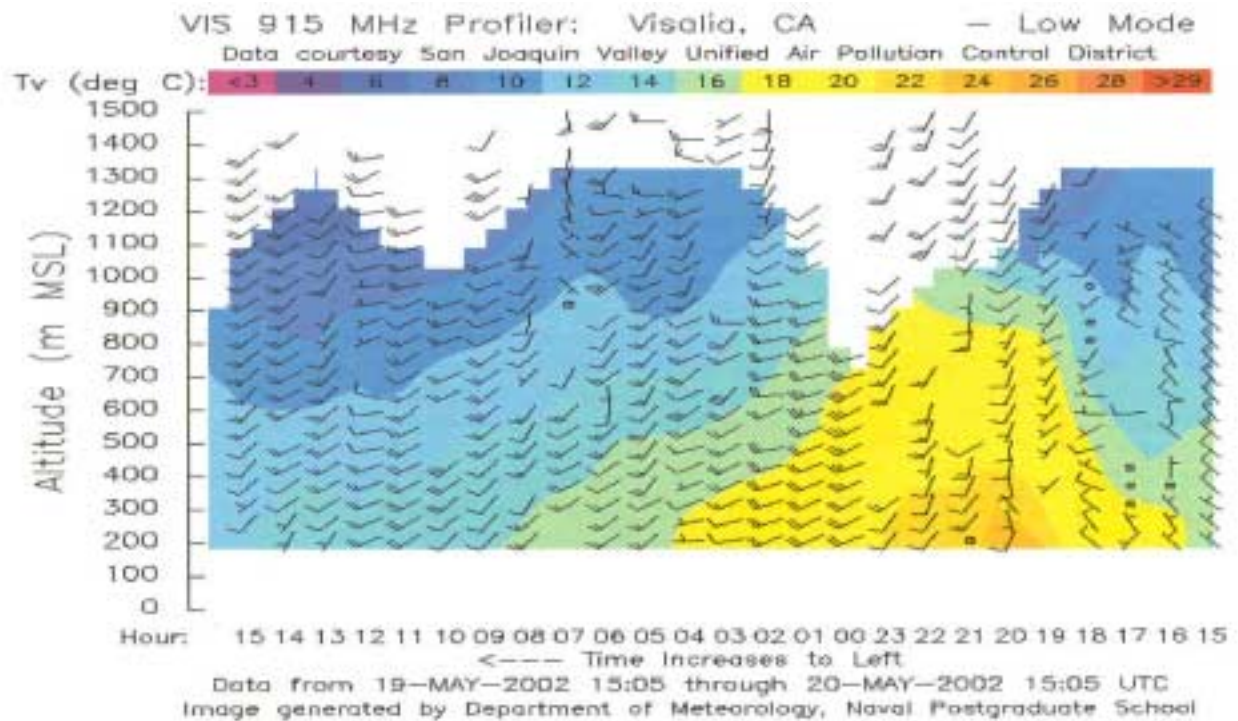
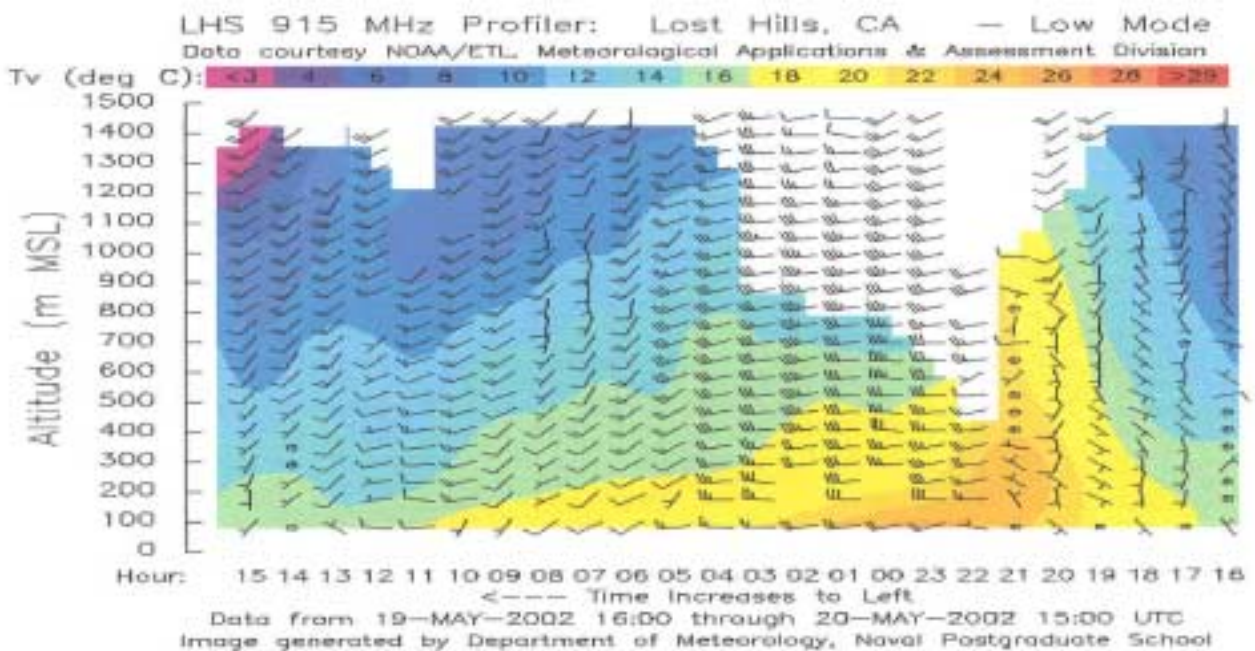


Figure 45: Lost Hill Lower Air Profiler Image for May 19-May 20th, 2002.



The wind event on May 19th, 2002 lasted six to eight hours and resulted in one real time monitoring site at McFarland (407 $\mu\text{g}/\text{m}^3$) exceeding the Federal 24-hour PM_{10} standard. Since other real time particulate monitoring sites did not register above the Federal 24-hour PM_{10} standard, the McFarland measurement signifies local wind and emission characteristics. The meteorology did suggest that winds were strong enough to reduce visibilities and impact locally other southern San Joaquin Valley communities during the peak of the dust event.

May 20, 2002

Isolated cases of wind blown dust continued across parts of the central and southern San Joaquin Valley on the 20th. At Bakersfield Golden, a 24-hour PM_{10} concentration of 189 $\mu\text{g}/\text{m}^3$ was measured, whereas at Bakersfield California, the PM_{10} concentration was 65 $\mu\text{g}/\text{m}^3$. **Table 26** outlines the Peak and Daily Average Particulate Matter Measurements at McFarland, Corcoran, Clovis, Fresno-1st, Bakersfield Golden and California. In order to understand the variability of these measurements, an in depth examination of the synoptic pattern and surface winds and observations, aircraft soundings, pibal balloon measurement, and lower air profiler measurements leading to the episode were analyzed.

TABLE 26: Peak and Daily Average Particulate Matter Measurements for sites across the SJV for May 20, 2002.

	10-Teom		10-BAM		2.5-BAM		FRM-10
Site Name	Peak	24-Avg.	Peak	24-Avg.	Peak	24-Avg.	24-Avg.
McFarland	*	45	*	*	*	*	*
Corcoran	45	12	45	20	22	11	15
Clovis	21	6	*	*	*	*	8
Fresno-1 st	*	*	*	*	10	1	7
Bak-Gold	*	*	*	*	*	*	189
Bak-Cal	*	*	*	*	*	*	65

*-N/A

units in $\mu\text{g}/\text{m}^3$

The meteorological synoptic analysis showed the jet stream carving a deep trough across central California on the morning of 20th. The morning surface charts depicted a strong surface cold front draped southwestward from Tonopah to Big Sur.

The 12Z surface pressure gradient was +4 millibars from San Francisco (SFO) to Las Vegas (LAS). A +4.0 millibars pressure gradient means onshore or down-valley flow.

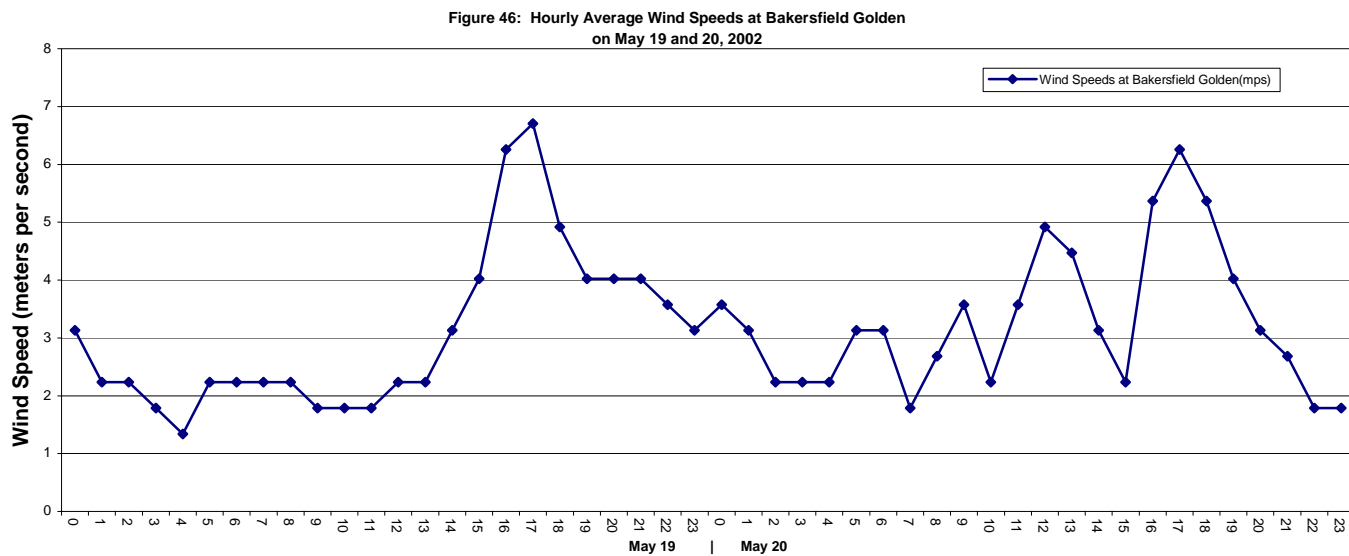
The morning temperature sounding over Fresno showed a weak inversion of 2 degrees Fahrenheit from the surface up to 500 feet turning unstable through 5,000 feet. At Bakersfield the temperature sounding showed an unstable atmosphere. The morning pibal measurement from Fresno depicted moderate to strong south-southwesterly flow from the surface up to 7,000 feet.

Upper level charts indicated a strong low 250 NM west of Eureka, with a broad trough covering the eastern Pacific and California. A strong temperature gradient at 850 MB and an intense upper level (300 MB) jet were evident across southern California on the 12Z analysis maps. Along with daytime heating, scattered thunderstorms developed across the southern San Joaquin Valley on the 20th. These thunderstorms coupled with an intense upper level jet, brought gusty winds across isolated parts of the Valley. In Madera, a small tornado touched down. **Table 27** shows the 24 hour daily average wind speeds at SJVAPCD air monitoring, ASOS, and CIMIS sites for May 20, 2002.

Table 27: 24 hour average wind speeds at SJVAPCD air monitoring, ASOS, and CIMIS sites for May 20, 2002.

SJVAPCD Air Monitor		ASOS		CIMIS			
	WS		WS		WS		WS
	MPH		MPH		MPH		MPH
BFLD-Gold	7.3	BFLD Meadows	11.2	FivePoints	10.4	Famoso	6.6
Clovis	5.9	Fresno YI	9.3	Shafter/USDA	8.1	Orange Cove	5.2
Fresno SSP	5.5	Hanford	8.9	Firebaugh/Telles	5.7	Madera	6.0
Madera Pump	6.3	Madera-AP	10.2	Stratford	7.9	Belridge	7.7
Maricopa	N/A	Merced-AP	7.2	Kettleman	4.5	Merced	3.3
Merced-Coffee	N/A	Modesto-AP	7.2	Visalia/Americas	4.2	Patterson	8.3
Parlier	8.2	Stockton-AP	6.7	Parlier	6.3	Lodi West	2.9
Tracy	7.9			Blackwells Corner	14.2	Tracy	5.8
Turlock	6.5			Los Banos	5.8	Porterville	4.6
Visalia LAP	7.3			Manteca	4.6	Lost Hills	11.2
				Modesto	7.2	Delano	N/A
				Fresno State	5.9	Westlands	6.1
				Lindcove	4.6	Panoche	5.8
				Kesterson	7.5	Arvin-Edison	5.3

Bakersfield Golden had higher wind speeds on the 20th compared to the 19th. **Figure 46** shows on the 19th wind characteristics at Bakersfield Golden were marked by a short duration event of elevated winds. On the other hand, the 20th was marked by gusty, strong winds occurring for most of the day. Peak one hour average wind speed measurements at Bakersfield California measured 13.8 mph at 18-19 PDT, with a 11.8 mph wind speed measured at 17-18 PDT and 19-20 PDT. At the Bakersfield ASOS a peak one hour wind speed measurement was 26 mph on the 20th. The wind event on the 20th at Bakersfield Golden resulted in a PM₁₀ measurement of 189 µg/m³; exceeding the Federal 24-hour PM₁₀ standard. Since Bakersfield California and other real time and Federal Reference Method (FRM) PM monitoring sites did not measure PM above the Federal 24-hour PM₁₀ standard, the Bakersfield Golden measurement signifies local wind and emission characteristics.



17.0 REFERENCES

Hackney, Richard, Larimer Xo, and Ranzieri, Andrew. 1991. Analysis of Upper Air Synoptic Parameters Relating to PM10 Episodes in the San Joaquin Valley. California Air Resources Board, Sacramento, California.

<http://www.arb.ca.gov/airways/CRPAQS/DA/PMEpisodes.htm>. June 24, 2004. PM Episodes: Central California Air Quality Studies – CCOS & CRPAQS. California Air Resources Board. Sacramento, California.